MEMOIRS

OF THE

GEOLOGICAL SURVEY OF GREAT BRITAIN,

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY

IN

LONDON.

VOLUME THE THIRD.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

THE GEOLOGY OF NORTH WALES,

BY

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LOCAL DIRECTOR OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

WITH MAP AND SECTIONS.

AND AN APPENDIX ON THE FOSSILS, WITH PLATES,

BY

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LATE PALÆONTOLOGIST TO THE SURVEY.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE:

PUBLISHED BY

LONGMANS, GREEN, READER, AND DYER.

1866.

[*Price* 13*s.* *in boards.*]

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NOTICE.

THE Memoir upon the Geological Structure of North Wales which is now published is, I consider, the most important work which has been issued by the Geological Survey during the ten years that have elapsed since I became Director.

Without this work our acquaintance with the details of the classification of the Lower Palæozoic Rocks would have been incomplete. As the author of the Silurian system, I beg further to express my sincere admiration of those successful labours by which Professor Ramsay and his associates carried out, over a very rugged, mountainous, and complicated region, the clearest proofs of the many great folds and dislocations which the Silurian strata have undergone, as well as for the great ability displayed in the delineation of all the various rocks of igneous origin.

By these researches the relative ages of the great dislocations were fixed.

The maps and sections of North Wales, in the preparation of which the labours of Ramsay, Jukes, Aveline, and Selwyn were united with those of my eminent predecessor, Sir Henry De le Beche, have now not only obtained a full description, but all the characteristic fossils, from the very lowest of the Silurian strata or the base of the Lingula Flags, are clearly described by our late Palæontologist, Mr. Salter.

I have, therefore, no doubt that this publication will give satisfaction to foreign as well as native geologists.

RODERICK I. MURCHISON,

Director-General.

Geological Survey Office.

PREFACE.

THE publication of this Memoir has been delayed considerably beyond the time when it was expected to appear, owing partly to the numerous occupations that fall to the lot of one who directs all the field work of the Survey, who edits its Geological Memoirs, and who, up to this time, has had to superintend the details of the publication of the numerous maps and sections issued. When in the middle of the composition of the work a serious illness, now removed, also for a time prevented the author carrying on any arduous literary and scientific labour.

The plan of the book is to give, first, a general sketch of the Geology of Wales, and then such a detailed description of Silurian rocks of North Wales, that any one may ascertain the structure of any minor area in which he may be interested. An index-map and many diagrams accompany the Memoir, but the special knowledge sought to be communicated can only be mastered in many cases by reference to the larger maps of the Geological Survey, published in sheets, on a scale of one inch to a mile, and to the sections, on a scale of six inches to a mile, which illustrate them. Nevertheless, for general purposes, the main geological features of North Wales may be understood by help of the index-map and diagrams that accompany this Memoir; and, indeed, by merely reading those parts that are printed in large type all the chief facts connected with the subject may be made out. It is evident that such a book would be incomplete without the Appendix on the Fossils, which has been prepared by Mr. Salter with that accurate knowledge of Silurian forms for which he is distinguished. Though such a work has nothing of a popular character in it, and makes very dry reading, yet it is likely not to be without use to those who, led by business or scientific pursuits, may feel it necessary to master the geological structure of North Wales.

ANDREW C. RAMSAY.

Geological Survey Office,
November 1865.

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THE GEOLOGY OF NORTH WALES.

CHAPTER I.

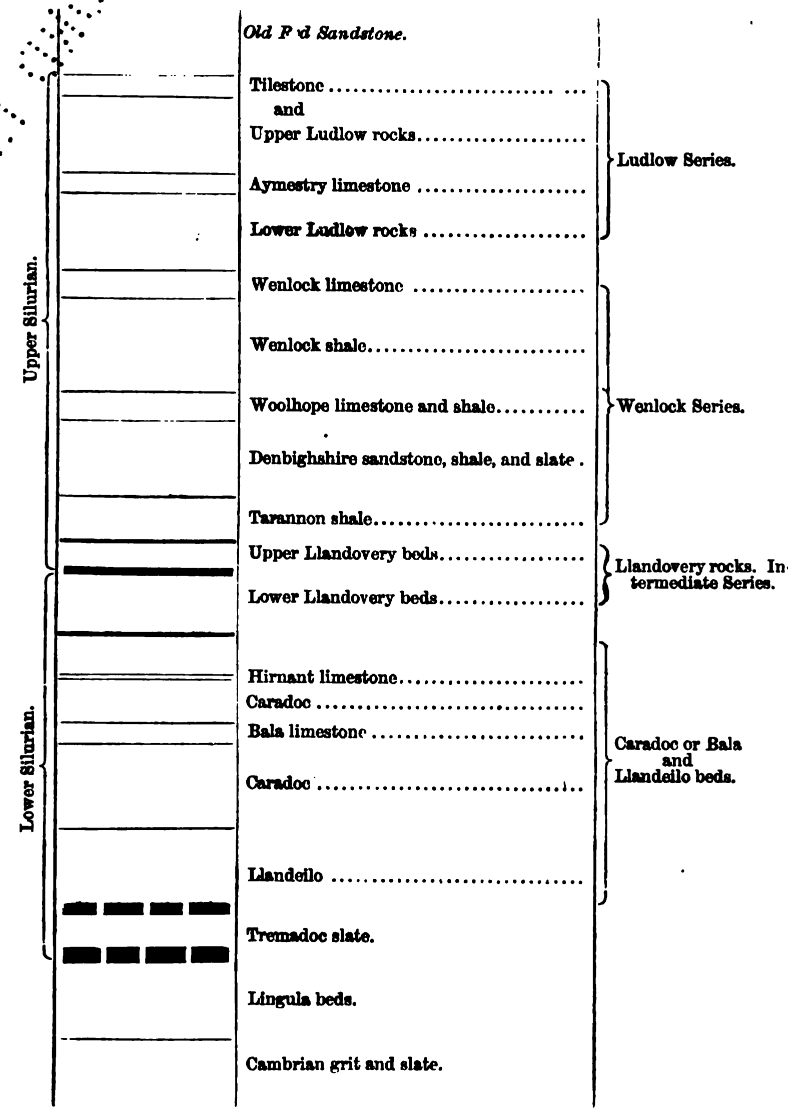
The Nomenclature of the Silurian and Cambrian Series.

The following column, showing the order of succession of the Silurian and Cambrian strata of England and Wales, is in its great, and in most of its smaller, divisions identical with those published in 1839 by Sir Roderick Murchison in the Silurian System. The chief differences consist in additions to our knowledge due either to the discovery since that period of new and subordinate divisions, or to the better understanding of the precise stratigraphical relations of members of the series.

With the exception of the Tremadoc slate, the divisions indicated in the column were all sanctioned by the late Sir Henry de la Beche during the progress of the survey; and all the modifications have been recognized by Sir Roderick Murchison in the last edition of "Siluria."

The thin dividing lines indicate that there is no marked stratigraphical break between the formations, and the thicker lines are intended to indicate the relative importance of the palæontological and stratigraphical breaks (unconformity) between the different members of the series. Where a dotted line occurs it implies that no geological line of division for these formations has been drawn on the maps. For lithological reasons that will appear further on, it never occurred to any one while the Survey of Wales was in progress to attempt to separate the Lingula and Tremadoc beds from each other, or from the overlying Llandeilo and Bala beds; but with increased knowledge and experience it might possibly now be done.

In no single area is the series quite complete; and in the form in which it stands in the column it has been built up from several districts and by several hands.



I shall now endeavour to give a brief history of the discovery of the different members of the series, the names that were given them, and the progress of those observations that extended over more than 20 years, and resulted at length in establishing their precise relations to each other. Each geologist in turn found it needful to modify his original views more or less, partly from the occasional excessive difficulty of understanding the arrangement of the rocks of some special district, partly from the local absence of one or more members of the series, without any visible unconformity to suggest it. Differences of opinion still exist, but chiefly respecting

names and classification, and though these may be interesting to individuals, they neither affect the order of stratification nor the palæontological facts, both of which can be readily understood by whatever names the strata are called. Minor points will continue to be discussed, while new fossils and new fossiliferous areas continue to be discovered. In Wales, as long as it is possible to refine in geological mapping, especially on the broad hills of Caermarthenshire and Cardiganshire, improvements in detail may be made, and it may be possible to divide the strata of that area into Lower Llandovery and Caradoc or Bala beds.

The micaceous sandstone called TILESTONE in Caermarthenshire and Brecknshire was described by Sir Roderick Murchison in a paper communicated to the Geological Society in 1833 (Proc. Geol. Soc., vol. i., p. 473), and afterwards in the "Silurian System," published in 1839. It was then considered as forming the base of the Old Red Sandstone. In 1842 it was mapped by Mr. T. E. James, under the superintendence of Professor Phillips, and referred by the latter and Sir Henry de la Beche to the top of the Ludlow rocks, with which its numerous fossils unite it. It has been allowed to remain there, though in Herefordshire and Shropshire there are symptoms of strata occupying the same position passing gradually into the Old Red Sandstone.

The LUDLOW ROCKS, the AYMESTRY LIMESTONE, and the WENLOCK LIMESTONE and SHALE were partly described in Shropshire and Herefordshire by Sir Roderick Murchison in the Memoir of 1833, and subsequently elaborated in the "Silurian System." The position assigned to these formations and the names then given them, have been universally accepted in British geology, and their equivalents have been described in many other regions.

The WOOLHOPE LIMESTONE and SHALE were at that period (1839) identified with the *Hollies limestone*, and called the *Caradoc* or *Woolhope limestone and shale*. The Hollies and the Woolhope limestone have, however, since been proved to be on different horizons; and the latter, being simply a subordinate part of the Wenlock series, was included in it by Sir Henry de la Beche and Professor Phillips in 1843, and published in that form shortly after in the maps and sections of the Geological Survey, and also in Professor Phillips' work on "The Malvern Hills," &c., published in 1848 in the "Memoirs of the Geological Survey of Great Britain," and this view Sir Roderick Murchison also adopted.

The DENBIGHSHIRE SANDSTONES were first described by Mr. Bowman, in 1841, as "coarse slates and flags with large Orthocera," and included by him as a subordinate part of the Upper Silurian rocks.* In 1842 Mr. Daniel Sharpe noticed these grits at Mallwyd, and described them as part of the Wenlock

* Reports, British Association, 1841.

series.* They were afterwards, in 1843, described by Professor Sedgwick,† and correctly stated to form a base to the Denbighshire flagstones, which he identified with the Upper Silurian rocks, their lower part being therefore the equivalent of the Wenlock shale.

In 1845 they were begun to be mapped by the Geological Survey, and lying beneath the commonly recognized Wenlock shale, they were for a time erroneously believed to be the western representatives of the Caradoc Sandstone of Shropshire and the "Pentamerus beds," then classed by every one as part of that series.

The TARANNON SHALES underlie the Denbighshire Sandstones, and by the Geological Survey were first considered to form the uppermost part of the Bala beds, but when the maps were nearly completed, Mr. Aveline began to suspect that they belonged rather to the Denbighshire Sandstone series, a suspicion entertained by Mr. Jukes before; and I believe at a much earlier date Professor Sedgwick had mentioned them as pale-coloured earthy slates or "paste rock." In 1855 I considered it necessary to define precisely the base of the Wenlock shale in the western parts of South Wales, a work that no one had previously accurately accomplished; and in accordance with the instructions of Sir Henry de la Beche, Mr. Aveline commenced the work. During its progress he detected the "pale" or Tarannon shales overlying the Upper Pentamerus or Llandovery beds near Builth; and as they elsewhere underlie the Denbighshire Sandstones, it became evident that these shales are on a higher horizon than the Upper Llandovery or Pentamerus beds of Shropshire, which are the equivalents of those of Builth.

The UPPER LLANDOVERY BEDS, first called Pentamerus beds and Hollies limestone (= upper part of MAY HILL SANDSTONE) were originally considered as the highest beds of the Caradoc Sandstone, and conformable with it. In first editions of the Maps and Sections the Geological Survey taking this view, overlooked these rocks in the country between Wenlock edge and Caer Caradoc, and the strip of Pentamerus limestone and conglomerate that laps round the Longmynds and the overlying Llandeilo flags, was considered as part of the true Caradoc Sandstone. The May Hill rocks were also thought to form part of that formation. In the Geological Journal for 1852, Professor Sedgwick and Mr. McCoy partly corrected these errors by showing that the fossils of the May Hill series were, to a great extent, distinct from those of the Caradoc Sandstone, and that they possessed more of an Upper than of a Lower Silurian character. Profiting by this hint, the Geological Survey re-examined the Shropshire rocks, and it was found by Mr. Aveline, and corroborated by myself, that the Upper Penta-

* Proc. Geol. Soc., vol. iv., p. 12.
† Proc. Geol. Soc., vol. iv., p. 18.

merus beds lie *quite unconformably* on the true Caradoc Sandstone, while Mr. Salter showed that the latter is by its fossils the precise equivalent of the Bala beds of North Wales. The fossils of these Pentamerus beds were also found to agree with those of May Hill, and the equivalents of the Tarannon shale were found to overlie them in Shropshire. The whole seemed to pass nearly conformably under the Wenlock shale. In 1854 Professor Sedgwick corroborated these views.* Physically the break between the Upper Llandovery beds and the Silurian strata below is complete. In Shropshire the unconformity is *visible*. The Upper Llandovery beds on the banks of the Onny lie on the higher part of the Caradoc Sandstone (= Bala beds), and as they strike northward gradually overlap the higher strata, till, on the banks of the Severn, near Buildwas Abbey, they rest on the lower beds of the same formation. A few miles from Wenlock edge they lie on the nearly vertical edges of the Cambrian or Longmynd rocks, and also on Lingula and Landeilo flags, between Church Stretton and Chirbury. In South Wales, between Builth and Newbridge, they lie equally unconformably on the Llandeilo flags, but 14 miles off at Noeth Grug they rest on the Lower Llandovery beds (which are higher than any part of the Caradoc Sandstone of Shropshire); but again, they rapidly creep across these to the south-west, and in the river Sawdde the Upper Llandovery beds lie directly on the Llandeilo flags. There is no unconformity so complete as this yet observed in other members of the British Silurian strata from the Llandeilo flags upward.

The Lower Llandovery Beds at Noeth Grug, near Llandovery, underlie the Upper Llandovery formation. In mineral character they so strongly resemble each other that up to 1856 no geologist distinguished between them, and when in that year it was found that in neighbouring districts only the uppermost of the Noeth Grug beds existed (Upper Llandovery or Pentamerus beds), it was then clearly necessary to attempt the task of separation. While engaged on this work Mr. Aveline found it lithologically a work of considerable difficulty. Nevertheless this difficulty soon ceased in consequence of the rapid overlapping of the Lower by the Upper Llandovery beds, so that the apparent local conformity may be accidental.

The Caradoc Sandstone was first noticed by Sir Roderick Murchison in the Proceedings of the Geological Society in 1833, and in 1834 these rocks were described by him under the name of Horderley and May Hill Sandstone. Subsequently, in the Silurian System (1839), these strata were called Caradoc Sandstone from the circumstance of their being typically developed in the neighbourhood of Caer Caradoc. The lists and plates of fossils included as part of this series those of the Pentamerus beds.

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* Philosophical Mag. for Oct. and Nov.

In 1838 certain rocks were descried by Professor Sedgwick in the Proceedings of the Geological Society, under the name of Bala beds, forming the upper part of his Cambrian series. They were then supposed to lie below the recognized Silurian rocks, though some of their fossils were known to be the same. In 1840 Mr. Bowman recognized their Silurian character from their fossils, and remarks that if there be a boundary between Silurian and Bala beds, it must be defined by other than fossil evidence. In 1842 Mr. Daniel Sharpe also concluded correctly from their fossils that they were the equivalents of the Lower Silurian rocks generally,* while in 1845 and 1846 the Geological Survey proved that they formed part of a series of rocks that in South Wales had been admitted as members of the Silurian series since 1842. In his anniversary address, as President of the Geological Society, in the year 1842, Sir Roderick Murchison also stated that "the term Cambrian must cease to be used in zoological "classification," with respect to the Bala beds of North Wales, &c., and that "the conventional line which has been set up in the "map of the Silurian region, between the Lower Silurian and the "Cambrian rocks, has no longer any reference to strata identified "by distinguishing organic remains, for the same fossils are "found in strata on each side of that demarcation."† In 1853 Mr. Salter examined the fossils of the district on the ground, and determined that they were generally identical with those of the Caradoc Sandstone. Caradoc Sandstone and Bala beds are, therefore, equivalent terms, the former ever since the publication of the "Silurian System" in 1839 having been used to express the higher part of the Lower Silurian series, while in 1838 the name of Bala beds for equivalent strata was used by Professor Sedgwick to express the higher part of the Cambrian rocks, at that time, and for several years after, generally believed to be older than any formation of Silurian age.

The LLANDEILO FLAGS were first named *Trilobite Schists* by Sir Roderick Murchison in 1834 in his descriptions of the Shelve country, the Carneddau, near Builth, and of the neighbourhood of Llandeilo, and under this name, near Shelve, were included the strata as low as the base of the Stiper stones, the whole of these rocks being older than the Caradoc Sandstone. Since 1848 the Geological Survey have been in the habit of considering the slates close below and above the Arans and Arenigs, &c. of North Wales, as equivalent to the Llandeilo flags of Builth and Shelve.

At the time of the publication of the "Silurian System," and for several years after, it was generally believed that all the rocks of South Wales in Cardiganshire, North Pembrokeshire, and other districts were assumed to be altogether of older date than the Llandeilo flags, and were therefore called Cambrian.

* Proc. Geol. Soc., vol. iv., p. 10.
† Proc. Geol. Soc., vol. iii., p. 642.

In 1842 I discovered that the Silurian beds on the banks of the Towey in Caermarthenshire were repeated further north in numerous undulations. I informed Sir Henry de la Beche, who at the same time confirmed the facts by a series of independent observations. Shortly after, in the same year, I found *Pentamerus lens* and other Silurian fossils in certain bands of grit and conglomerate near Dolaucothy, and this first led to the strata between the Towey and Cardigan Bay being thrown into the Silurian series.

TREMADOC SLATE.—These strata were long ago (1846) described by Professor Sedgwick on special lithological grounds, but it was not till after 1857 that Mr. Salter determined by their suite of fossils that they deserve to be ranked as a distinct formation, very few of the forms occurring either in the Lingula flags below or the Llandeilo flags above.

The LINGULA FLAGS were first named in consequence of Mr. Davis's discovery of Lingula Davisii in these rocks near Tremadoc, in 1845, for this fossil was soon found to be so characteristic, that it gave a name to the formation; but, forming with the overlying rocks a slaty series not easily distinguishable lithologically, no one up to this time has precisely divided them on maps from the formations above.

The CAMBRIAN ROCKS of the Longmynd were in "The Silurian System," shown by Sir Roderick Murchison to underlie the whole of the Silurian strata, and when in 1846 and 1848 the Geological Survey mapped the equivalent rocks in Merionethshire and Caernarvonshire, they naturally adopted this name for these deposits. Stratigraphically they occupy the same position, and lithologically they much resemble each other.

COLOURING OF THE MAPS.—In 1841 the Geological Survey began to map the Silurian rocks at Haverfordwest in Pembrokeshire, and Sir Henry de la Beche was unable in that neighbourhood to detect any base for the Silurian strata. In the same year at St. David's I traced a provisional line between the black and the purple slates, and this was afterwards adopted as the line between the Silurian and Cambrian strata. In 1841 Sir Henry de la Beche also discovered graptolites in the black slaty rocks of Fishguard near the fort, and about the same time Mr. Aveline found traces of fossils at Dinas Head on the same coast. Previous to this time Mr. Henry McLauchlan had found *Calymene duplicata* at Abereiddy Bay and other fossils elsewhere between Fishguard and St. David's Head, and soon after I found *Didymograpsus Murchisoniæ*, *Lingula Ramsayi*, and *Bellerophon perturbatus* at the same slate quarries. Graptolites were also found by Sir Henry de la Beche near Cardigan, and in the spring of 1842 fragments of Silurian looking fossils were found by me near Newcastle Emlyn. I also found encrinites several miles north of Caermarthen. The strata of all of these areas were, however, up to these dates generally presumed to be older than the Llandeilo flags of Sir R. Murchison, although these discoveries soon inclined Sir Henry de la Beche to believe that they might turn out to be of Lower Silurian age.

In June 1842, while working at Llandeilo, I discovered in so-called Cambrian ground, in a brook near Llwyd-coed-uchaf, shales and thin impure limestones and grits, dipping north, and full of Lower Silurian fossils. I concluded that they were Lower Silurian rocks rolled over to the north, and supposed them to form a part of the series higher than the trilobitic Llandeilo flags of Dynevor Park. A more recent analysis of the fossils by Mr. Salter shows, in fact, that they are Bala or Caradoc beds, and this agrees with the position I assigned them. I immediately informed Sir Henry de la Beche of the circumstance, and a single day later he detected similar appearances near Llangadoc. In August of the same year I found *Pentamerus lens* at Melin-newydd, near Pumpsant, and generally identified the strata with the well known Pentamerus beds of Noeth Grug. Pursuing these investigations the whole of South Wales as far as Cardigan Bay was shown to be simply a repetition of Lower Silurian strata, prolonged in numerous undulations, and it was therefore (no one for years objecting) coloured Lower Silurian. We believed, however, as we proceeded northward that we might at length reach a lower set of fossiliferous Cambrian rocks, but found instead the recognized Lower Silurian strata, striking directly into the Bala country. Hence the greater portion of Wales, under the name of Llandeilo and Bala beds, came to be coloured Lower Silurian by the Geological survey; and it was not till we reached the barren purple and green grits and slates of Merionethshire lying below the Lingula flags, that we mapped (as Cambrian) any formation distinct from the great fossiliferous Lower Silurian series.

CHAPTER II.

Geographical Arrangement and Physical Relations of the Palæozoic Rocks of Wales and Shropshire.

The following Memoir relates chiefly to the rocks of Merionethshire, Caernarvonshire, Anglesey, and part of Denbighshire, but before proceeding to detailed description of this area, I shall attempt to give an idea of the general geographical disposition of the Silurian and Cambrian rocks of Wales and its neighbourhood, and of their local relations to those later members of the Palæozoic series that chance to bound them.

The oldest rocks in Wales and Shropshire rise to the surface in six districts:—

First, Anglesey, the greater proportion of which consists of mica and chlorite schists, gneissic rocks, grits, and quartz-rock.

Second, the Bangor and Llanberis district, comprising the altered purple, green, and chloritic, slaty, arenaceous, and con-

glomeratic beds west and south-west of Bangor; together with the purple and green slates, and grits on the banks of the Ogwen around Bethesda, the lakes of Llanberis, Llyniau Nant-y-llef, and Llanllyfni.

Third, the Lleyn district, consisting of the ancient schists on the south side of Caernarvon Bay, including Bardsey Island and the coast from Bardsey Sound to Porth Nevin.

Fourth, the Harlech district, an oval-shaped tract, occupying most of the ground between the Barmouth estuary and that of Traeth-bach, and principally composed of greenish grits, occasionally interstratified with green and purple slates.

Fifth, the district of St. David's, comprising the purple sandstones and slates on the north side of St. Bride's Bay, in Pembrokeshire.

And sixth, the purple and green grits, conglomerates, and slaty beds of the Longmynd, and the neighbourhood of Shrewsbury.

The term *Cambrian* is restricted in this Memoir to the rocks mentioned above, which, excepting annelide burrows, and a doubtful trilobite, have nowhere yielded in England or Wales any well authenticated organic remains. The strata that lie between them and the Old Red Sandstone are called *Silurian*, on the ground that in Shropshire and in part of South Wales they were so originally termed by Sir Roderick Murchison.* This name was subsequently extended over Wales by the Geological Survey to areas previously considered older, but found to be of identical date. Although there are great generic and specific differences in the fossils of some of the Silurian formations, trilobites, cystideæ, brachiopods, &c. are found throughout, and graptolites everywhere except in the Lingula flags.

1. *Anglesey.*—In Anglesey the Cambrian rocks are overlaid by Lower Silurian shales and grits, which principally lie in the central part of the island, north, north-east, and south-west of Llanerchymedd. The Old Red Sandstone and Carboniferous Limestone rest on them unconformably in a broad strip between Dulas Bay, Red Wharf Bay, and Malldraeth Sands. A succession of faults that follow a straight course from Red Wharf Bay to Llanddwyn Island, throw the Carboniferous Limestone and Permian rocks against the Cambrian schists that occupy the south-east quarter of the island. A patch of Silurian rocks overlaid by limestone rests on these schists between Llanfihangel, Puffin Island, and Beaumaris, and the same limestone, with occasional beds of sandstone, bounds the schists on a line between Llanfair-pwll-gwyngyll and Newborough Marsh. A small patch of red unproductive Coal measures rests on the limestone opposite Caernarvon.

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* The rocks beneath the Stiper Stones, which probably represent the Lingula flags, were however not known under this name originally, but have since been included with them.

2. *Caernarvonshire.*—The Cambrian rocks of part of the north-west of Caernarvonshire belong geographically to the same area as those of Anglesey, being only separated from them by the Menai Straits. In both areas the Carboniferous rocks rest unconformably upon them. A band of unproductive Coal-measures forms a narrow strip of coast line between Caernarvon and Llanfair-is-gaer, and is succeeded by a belt of Carboniferous Limestone from thence to Gored-girth on the coast near Bangor. A fault throws these rocks against a felspathic mass of granitic character, that lies between Caernarvon and Bangor, and (except near its northern termination) separates the Carboniferous strata on the Menai from the Silurian and Cambrian rocks of this part of Caernarvonshire. The last-named strata, repeated by a north-east fault, lie in two patches, one between the Lavan Sands and Caernarvon, and another running from Nant Ffrancon by Llanberis to Llanllyfni.

3. *Lleyn.*—The third Cambrian area, much metamorphosed, forms a broad belt of land between Bardsey Island and Porth-dinlleyn. It is bounded on the south-east by the Lower Silurian rocks of Lleyn,* through which are protruded numerous bosses of greenstone, &c., in the area that lies between Aberdaron, Criccieth, and Yr Eifl or the Rivals.

The Cambrian rocks near Llanberis and Bethesda are overlaid by the Lingula flags, and these are succeeded in ascending order by strata, the higher part of which represents the Bala beds or Caradoc sandstone of Sedgwick and Murchison. Magnificent sections of these rocks occur in the Passes of Llanberis and Nant Ffrancon, and on the heights of Snowdon, Y Glyder-fawr, and Carnedd Llewelyn, and, indeed, in the entire series of slaty rocks, interstratified with ingneous products that lie between the Vale of Conwy and Caernarvon Bay.

4. *Merionethshire.*—The fourth Cambrian area is the oval-shaped mass of Merionethshire, between Traethbach and the estuary of the Mawddach, the grits and conglomerates of which are surrounded on the north-east and south by the Lingula flags, dotted with occasional protrusions of greenstone. Above these Lingula flags lie the Tremadoc slates, which are overlaid by great accumulations of volcanic ashes, principally felspathic, and of felspathic traps or lava flows, extending in a crescent form round the Cambrian, Lingula, and Tremadoc beds, and forming the heights of Cader Idris, and the Arans, Mynydd Nodol, Craigddu, the Arenigs, the two Manods, and Moelwyn-mawr and Moelwyn-bach. It will be shown that this volcanic series was of much earlier date than that which forms the high mountain tracts in Caernarvonshire, between Tremadoc, Llanrwst, and Conway. The former lies about the horizon of the Llandeilo flags, the latter in the middle of the Bala beds or Caradoc

* Lleyn is the Welsh name of the promontory that separates Caernarvon Bay from Cardigan Bay.

sandstone. Till the districts were mapped by the Geological Survey, they had been described by geologists as the same.

Caradoc or Bala Beds.—The typical Bala or Caradoc beds lie in the Bala district between Dinas Mowddwy, Bettws-gwerful-goch, and Bettws-y-Coed. They consist of black and blue slates, and grey and brown arenaceous beds, the Bala limestone, generally very impure, lying about the middle, and averaging from 20 to 30 feet in thickness. Between the limestone and the lower traps of the Arenigs and Llyn Conwy, two and sometimes three thin and imperfect beds of volcanic ashes represent the whole of the vast volcanic accumulations of Moel Hebog, Snowdon, and Carnedd Llewelyn. The middle part of the Bala beds, including the limestone, is most fossiliferous, the black slates below, and the slaty and sandy interstratifications above, being comparatively barren.

5. *St. David's, Pembrokeshire.*—Eastward the Bala beds are overlaid by a part of the Lower Llandovery beds, and passing southward, these, prodigiously thickened, and together with a smaller development of the ordinary Caradoc or Bala beds, range through large portions of the western parts of the counties of Montgomery, Radnor, Brecon, Cardiganshire, and the northern halves of Caermarthenshire and Pembrokeshire. In Pembrokeshire igneous rocks, resembling those of North Wales, are associated with Llandeilo slates, beneath which at Whitesand bay occurs a thin band of Lingula flags, and at the bottom of all, on the north side of St. Bride's Bay, the fifth Cambrian patch rises to the surface, consisting of purple slates and grey and purple sandstones and conglomerates, resembling their equivalents in Caernarvonshire.

6. *The Longmynd.*—The Cambrian rocks of the sixth area crop out from beneath those equivalents of the Lingula flags that lie immediately east of the Stiper Stones. On the south, and partly in the south-east, they are enclosed unconformably by the Upper Llandovery rocks, or Pentamerus sandstone, conglomerates, and limestone (equivalents of the May Hill sandstone), and partly by the Wenlock shale. On the east, about Church Stretton, they are partly bounded by Caradoc rocks and Wenlock shale, thrown against them by faults, and from Le Botwood, north and westward they are enclosed by Coal-measures, Permian rocks, and New Red Sandstone. The Lingula and Lower Llandeilo beds, that overlie the Cambrian rocks of the Longmynd on the west, are encircled by the Pentamerus and Wenlock beds, which rest on them in the same unconformable manner that they do on the Cambrian grits of the Longmynd.

A long strip of Caradoc sandstone or Bala beds runs from the Wrekin near Coalbrook Dale by Caer Caradoc, for 20 miles to the south-west. It is separated from the Wenlock and Tarannon shale by the same Upper Llandovery rock beds that underlie that formation on the flanks of the Cambrian and Lower Silurian rocks of the Longmynd and Shelve, and also west of the Wye near

Builth, and in Caermarthenshire north-east and south-west of Llandovery. In all these areas there is a marked unconformity between the Upper Llandovery rocks and the underlying strata of whatever age.

Llandovery Beds and Tarannon Shale.—In North Wales the Upper Llandovery rocks are absent, and the Bala beds, as far north as the ground 6 miles south-east of Bala Lake, are (as already stated) overlaid by a long strip of grit probably belonging to Lower Llandovery strata, and this is overlaid by pale grey, purple, and green Tarannon shales.* These shales (the Upper Llandovery beds being absent) form the lowest part of the Upper Silurian rocks of North Wales, and on the west of and below the Denbighshire grits they run in a narrow and nearly unbroken line from the mouth of the Conwy to Melynllyn near Llanddewi Ystrad Enny, at their southern end being strikingly unconformable to the various underlying members of the Lower Silurian strata. On the sides of the boss of the Llandeilo flags of Builth they are absent, but appear in force on the banks of the Wye near Newbridge, resting on Bala beds and Lower Llandovery rocks, and further south towards Garth (where they are overlapped by Wenlock shale) on Upper Llandovery beds. They next appear from under the Wenlock shale at Noeth Grug, and strike south-westerly near Llandovery to the neighbourhood of Pen-y-lan, resting on Upper Llandovery beds. Near Pen-y-lan the Tarannon shales are overlapped by the Wenlock shale and they do not again appear in South Wales.

On the north-west flanks of the Berwyn area the Tarannon shales separate the Denbighshire grits from the Bala beds. On the south they are partly cut off by a fault along the range of Pen-y-bylchau, but again appear in the country near Llanfyllin and Meifod. The same shale runs along the south flank of the hills of Cyrn-y-brain north of Llangollen, and of another patch of the Bala beds east of Llanelidan.

Denbighshire Grits.—The Denbighshire grits succeed the Tarannon shale, and, interstratified with slaty shales, form the base of the Wenlock strata. They run from north to south, in a long sinuous and sometimes broad strip, from the mouth of the Conwy to Melenydd, immediately north of Llanddewi-ystrad-enny, in Radnorshire. East of Bala Lake they lie in a trough, from two to four miles wide, and the Tarannon shale and Lower Silurian rocks of the Berwyn hills rise from underneath their eastern boundary, similar in general structure to those of Bala and Caernarvonshire, but with the igneous rocks are much less largely developed.

North of the Berwyn hills between Llangollen and Corwen the Denbighshire grits, more shaley in character, overlie the Tarannon shales; and in the valley of the Vyrnwy and eastward

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* For more detailed notice of the Llandovery beds see pp. 15 and 230.

by Welshpool and the Longmountain, and round the Lower Silurian rocks of the Shelve and Corndon country, this sandy character of the base of the Wenlock Shale has entirely disappeared.

In Radnorshire, 10 or 12 miles north of Builth, the Denbighshire grits die out, but their equivalents in a more shaley form are believed by Mr. Aveline to strike into South Wales. This shaley variety also probably forms part of the formation in the typical country near Wenlock Edge, as well as in Caermarthenshire, where in places these strata rest capriciously, sometimes on the Upper Llandovery beds, sometimes on the Caradoc Sandstone or Bala beds, and near Builth and west of Llanarthney on the Llandeilo flags.

Wenlock Shale.—Between the mouth of the Conwy and Corwen the Denbighshire grits are succeeded by ordinary Wenlock shale.

West of Llanarthney in Caermarthenshire the Upper Silurian rocks disappear, and the Old Red Sandstone and Carboniferous strata lie directly on Lower Silurian beds.

Old Red Sandstone and Carboniferous Rocks. — From Denbighshire to Pembrokeshire the whole of the Silurian rocks of Wales and Shropshire are set in a framework of Carboniferous and Old Red Sandstone strata. Striking from Anglesey across the entrance of the Menai Straits, the Carboniferous Limestone rests on the Bala beds at the Great and Little Ormes headlands, but from thence to Llanelidan it lies on Upper Silurian shales and flagstones in a long band rarely more than 2 miles in width. Here and there narrow strips of Old Red Sandstone intervene,* and the whole of these dip north-east into the vale of Clwyd, where the limestone is overlaid by a low expanse of New Red Sandstone. From beneath this Secondary rock on the east, thin interrupted strips of limestone again crop out, reposing on the Upper Silurian hilly range east of St. Asaph and Ruthin, which like a great barrier divides the limestone in the Vale of Clwyd from that on its eastern flanks. The base of the Carboniferous Limestone lies highly unconformably on the Silurian strata, and its upper beds are overlaid by the Denbighshire coal-field.

The same limestone bounds the Silurian territory as far south as Llan-y-mynych, lying on the Caradoc or Bala beds at Cyrn-y-brain, on the Wenlock shales and flags near Llangollen, and again on the Bala beds east of the Berwyns. Following the Silurian line to the south between the Breidden hills and Le Botwood in Shropshire, the Coal-measures lie indifferently on Upper and Lower Silurian and Cambrian rocks, and between Coalbrook Dale, and Llanarthney in Caermarthenshire, the Old Red Sandstone, sweeping across Herefordshire into South Wales, rests directly and

* The strata which in places contain Cornstones have always been considered Old Red Sandstone. They, however, belong to that uppermost part of the formation which some authors now consider to be closely allied or actually belonging to the Lower Carboniferous series.

apparently conformably on Upper Ludlow rocks, till in Caermarthenshire it gradually creeps across the Upper Silurian strata, and bounds the Llandeilo flags on the south as far as the eastern Cleddau, near Slebech, in Pembrokeshire. Beyond Slebech in its turn it is overlapped by the Carboniferous Limestone, and from the western Cleddau to the north-east angle of St. Bride's Bay, the Coal-measures rest directly on the Lower Silurian strata.

Physical Relations. — The principal physical relations of the Silurian and Cambrian strata of Wales may be briefly stated as follows:—There is no sign of unconformity anywhere between the Cambrian rocks and the overlying Lingula flags of Merionethshire, Caernarvonshire, and the Longmynd.*

The beds known as Tremadoc slates succeed the Lingula flags. They are best known in the district from whence they take their name, and are characterised by the presence of *genera* of *trilobites*, and brachiopoda, many of which are not found in the underlying true Lingula flags, and some of which pass upwards into the Llandeilo and Caradoc series. They have, therefore, an independent character of their own, which, however, is more nearly allied to that of the Lingula flags than to that of any overlying formation. Occurring apparently only in isolated patches, they probably lie unconformably on the Lingula flags, although this has not been actually proved.

The Llandeilo flags come next in the series. These are largely developed in the typical district of Llandeilo, and more or less along the Silurian country a few miles north of the base of the Old Red Sandstone of South Wales, and their equivalents succeed the Lingula flags of Pembrokeshire, and probably form the lowest strata of the vale of Teifi and other parts of South Wales. They are characteristically developed in association with the igneous rocks of Builth, and of the Shelve district west of the Longmynd, and they form the lowest strata exposed in the centre of the Berwyn hills. The black slates that circle round and immediately overlie and underlie the igneous rocks from Cader Idris in Merionethshire, to Moelwyn in Caernarvonshire, also most probably represent the same series, but in the absence of fossils it is impossible to be quite certain. Certain strata in Anglesey may also be of the same age. Resting as they do in Scotland and Ireland unconformably on Cambrian strata, it is likely that there is also an unconformity between the Llandeilo flags and the Tremadoc and Lingula beds even in Wales, for though there is no visible break between any two of the above-mentioned formations, in Anglesey strata of Llandeilo and Caradoc age lie directly on Cambrian rocks, showing so great

* In Sutherlandshire and in Ireland there is a marked unconformity between the Llandeilo and Caradoc beds and the Cambrian rocks, the Lingula flags being absent, and the same seems to be the case in Caernarvonshire, near the Menai Straits, and in Anglesey.

and rapid an overlap of the Lingula and Tremadoc series, that it seems to indicate unconformity between these black slaty strata and the Tremadoc and Lingula beds below.

There is no sign of unconformity between the Llandeilo rocks and Bala or Caradoc beds, whether in the country near Llandeilo, among the Berwyn hills, or in any other part of Wales.

Classification of the Llandovery beds and Tarannon shale.

The next point that arises is the relation of the Lower Llandovery beds to the older strata. These appear on the east side of the Bala series, south-east of Bala, whence striking south in a well-defined strip to Mallwyd, they gradually thicken and widen out, and rolling over to the westward, they seem to form a large proportion of the rocks of Cardiganshire, West Montgomeryshire, Radnorshire, North Caermarthenshire, and part of Pembrokeshire. In general they are almost unfossiliferous, but between Rhayader and Builth, and near Newbridge, and in Caermarthenshire, between Noeth-grug and Llandovery, they contain numerous fossils (*see* p. 231). Sometimes they seem to pass lithologically into the Caradoc or Bala beds, both of South and North Wales, and no certain unconformity has been detected between them, except possibly in Caermarthenshire near Noeth-grug. In the original typical country of the Caradoc sandstone of Sir R. Murchison, in Shropshire, the Lower Llandovery beds do not exist. These considerations, added to the circumstance that a large proportion of the fossils are Lower Silurian species, decided the Geological Survey to retain these strata among the Lower Silurian deposits, although by some persons it has been proposed to place the Lower and Upper Llandovery beds in a Middle Silurian series.

The Upper Llandovery beds come next in the series. In South Wales they first appear in Marloes Bay, and, at intervals, range across Pembrokeshire; but further north and east they disappear for a space, being overlapped by the Old Red Sandstone. They re-appear south of Llandeilo, in Caermarthenshire, lying at the base of the Upper Silurian rocks; and varying from a few feet to 1,000 feet in thickness, they range north-east in a narrow strip through parts of Caermarthenshire, Breconshire, and Radnorshire, lying indifferently and unconformably on Lower Llandovery, Caradoc, or Llandeilo beds. Near Builth, only a few feet thick, they rest quite unconformably on the Llandeilo flags and their associated igneous rocks. They are also found near Presteign, at Nash Scar, and in Shropshire they lie very unconformably on the Caradoc sandstone, between the neighbourhood of Cardington and Coalbrook Dale. In the Longmynd country they also lie quite unconformably in the form of a calcareous conglomerate on Cambrian and Lower Silurian rocks, and beyond this in Wales they are not known anywhere at the western base of the Upper

Silurian strata between Radnorshire and the mouth of the Conwy.

While the seeming conformity of the Lower Llandovery beds with the Lower Silurian strata point to a relationship between them, the decided unconformity of the Upper Llandovery beds on all below, indicates a closer connexion of these strata with the Upper Silurian rocks generally. In fact a great physical break takes place at this point, all the lower members of the Silurian series having been disturbed and planed across by denudation before the Upper Llandovery beds were formed. Accordingly, by the Geological Survey they are considered to form the basement beds of the Upper Silurian strata.

Though the Upper Llandovery beds do not occur in that part of North Wales which forms the main subject of this memoir, the foregoing explanation is necessary for the full understanding of the subject. The stratigraphical classification adopted in consequence of the physical relations of the strata is not contradicted by the fossils (*see* page 231).

The Tarannon shale, which comes next in the series, ranges from Caermarthenshire on the south to the mouth of the Conwy. It rises generally in a narrow band from beneath the western base of the Wenlock shale and Denbighshire grits. In the country near Llandovery (Noeth Grug, &c.) and west of Builth the shale lies directly, and apparently conformably, on the Upper Llandovery beds. A little further north the Tarannon beds overlap the Upper Llandovery strata, and between that point and the mouth of the Conwy in North Wales they lie transgressively and quite unconformably on various members of the Lower Silurian series. On the other hand, both in Wales and Shropshire they pass conformably under the lowest beds of Wenlock shale, with which undoubtedly they are intimately connected.

Above the Tarannon shale the Wenlock and Ludlow beds seem to have been formed in regular and unbroken succession.

The strata that lie between the top of the Caradoc or Bala beds and the base of the Wenlock shale, in my opinion, were formed during a period of frequent oscillation of the relative level of the land to the sea. This oscillation succeeded the long and continuous deposition of the Bala beds, and preceded the formation of the Wenlock and Ludlow strata. The Lower and Upper Llandovery beds and the Tarannon shale belong, in fact, to a middle portion of the Silurian epoch only. Three fragments of this episode have alone been preserved, and while the oldest, that of the Lower Llandovery beds, is somewhat closely connected with the Lower Silurian period, the remaining two are more nearly related to the Upper Silurian age.

To explain all of these phenomena that apply to North Wales more in detail will be one of the principal objects of this Memoir; and in doing this I shall not invariably follow either an ascending or a descending stratigraphical order, nor yet describe the details

of each entire section in succession, but rather allude to their points and peculiarities in any mode most desirable for the explanation of the physical geology of North Wales.

CHAPTER III.

The Cambrian Rocks of Merionethshire.*

General Range.—The Cambrian rocks of Merionethshire are comprised in a broad mountain tract, forming an irregular oval, of which the widest diameter from north to south is about 15, and from east to west about 10 miles.

The rocks of this region principally consist of coarse quartzose, greenish grey grits, the quartz grains being often associated with interspersed granules of felspar. The rock has often a semi-crystalline aspect, perhaps due in some cases to the original angularity of its component grains, and in others to the partial effect of what is termed metamorphic action. The beds seem to have been formed principally by the direct waste of rocks of a granitic character, or at least into the composition of which crystalline quartz and felspar largely entered. Occasionally the strata are conglomeratic, quartz, and more rarely felspathic pebbles, being disseminated in a gritty base. They are always hard and solid, and often very massive, attaining a thickness of 8, 10, or even 12 feet. Fine sections are so numerous that almost anywhere their general structure may be examined. Sometimes they are purple and fine grained, and they are intermingled with occasional bands of greyish green and purple slates, which, especially towards the lower part of the series, attain a considerable development. Excepting Annelide tracks and borings, no fossils have yet been observed in the Cambrian strata of Merionethshire.

Sections.—The Cambrian rocks are bounded by a sinuous line from Barmouth to Dol-y-melynllyn,† near the fifth milestone north of Dolgelli. From thence it bends north, crossing the turnpike road and Afon Eden near the sixth milestone, and Afon Gain close above Rhaiadr Mawddach. Beyond this it passes along the east slope of Craig-y-Penmaen, and afterwards, partly bounded by a north and south fault, the line crosses the Ffestiniog road about a mile north-east of the spot where the roads branch to Ffestiniog and Maentwrog. A few hundred yards further north, the boundary suddenly leaving the line of fault, strikes to the south-west by various houses called Llenyrch, Dolorgan, and Glyn-cywarch, after which it enters the marsh of Morfa Harlech, and bending to the north beneath the alluvium, again takes a westerly course on the hilly ground by Llanfihangel-y-traethau, and passes from Bryntirion towards the blown sand west of Glan-y-mor. From thence to Barmouth it is bounded by the marsh and the sea, but under water the boundary perhaps strikes westward towards the promontory of Penrhyn-du on the north coast of Cardigan Bay.

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* Map 75, N.E., S.E., and 59 N.E.

† Mis-spelt *Dol-y-melynen* in the map.

Near Barmouth the strata are beautifully exposed on the hill sides towards Aber-rhamffroch, dipping E.S.E. at angles of about 50° and 60°. They are composed of coarse quartzose grits of a grey colour, with a tinge of green. Semi-transparent grains of blue quartz are common in these. Throughout the whole section there are thin bands of greyish green and occasionally of purple slate, a good example of which occurs at the ferry, close by the landing place. The junction with the Silurian strata, afterwards to be described, is at Aber-rhamffroch.

Another beautiful section occurs about 5 miles north-east of Barmouth, on the west side of Y-foel-fechan, where on a high and steep hill side there is a clear exposure of these rocks, bed after bed dipping south at low angles over a distance of about a mile. On Clogau the beds maintain the same dips, and from thence to Pont-ar-Gamlan they gradually curve round and dip south-easterly under the Lingula flags of Cwm-gwain and Cefn-coch. From Pont-ar-Gamlan towards Trawsfynydd they dip nearly east, and all these dips being on an average greater than the slope of the hills, lower beds gradually crop out on the north and west. A broad anticlinal axis runs up the centre of the great flats, that extend from the north end of Cefn Cam to Cors-goch near Trawsfynydd, and this arrangement of the beds immediately north of Craig-y-ganllwyd and Cefn Cam, is well shown in the horizontal sections, sheet No. 37, lines 1 and 2. The lowest Cambrian beds run north to Dolwen, where they are concealed by drift and alluvium, but judging by the superficial débris, they probably consist in part of purple slate. A curved line drawn from thence, averaging about 5° west of south, would give the continuation southwards of the lowest exposed beds of the Cambrian anticlinal curve. On the rough hills, traversed by the Roman road, on the east side of the anticlinal, great beds may be seen rising in terrace-like steps, dipping east, at angles varying from 25° to 30°. The same beds roll over to the west, forming the magnificent mountain escarpments of Llether, Rhinog-fawr, Rhinog-fach, and Craig-ddrwg, where the strata dips towards the sea, and so barren are the rocks that even from the Dolgelli and Ffestiniog road, on a clear day, layer above layer may be followed by the eye along the whole eastern face of the mountains.

In the pass of Bwlch-drws-ar-dudwy, the rocks are singularly bare of vegetation, and for a height of about a thousand feet from the base to the very summit of the hills, the beds piled on each other may be seen dipping steadily west, with gentle undulations, at angles varying from 25° to 30°, presenting one of the grandest spectacles, both geologically and as a piece of rugged scenery, that North Wales affords. Rhinog-fawr forms one side of this pass, and the disposition of its rocks will be well understood by reference to the horizontal section Sheet No. 37, line 1. From thence to the sea the beds undulate, so that the strata that crop to the surface about the centre of the Merionethshire anticlinal line on Afon Eden rise again near Harlech, and for some miles further south. Purple slates occur near the coast and in several of the valleys south of Harlech. Towards Ffestiniog the same grits dip northerly,* the east bend of the curve being cut off by a large fault,† so that the Cambrian strata and the Lingula beds abut on each other, both dipping to the north at angles under 30°. In the centre of this anticlinal curve purple slates, underlying all the grits, rise in mass sufficient to allow of the opening of small quarries, but the form of the ground being generally unfavourable for such operations, the depth of slate is unknown. In most of the greater sections conglomerates occasionally occur, and false bedding, together with ripple or current marks are not unusual. The greatest measured thickness is from 6,000 to 7,000 feet, but the base of the formation is unknown, either on the coast or in the anticlinal curve, between Trawsfynydd and Cefn Cam.

The total thickness (Section 3, Pl. 28) between Gwyn-dy and the Lingula flags on the N.W. is about 4,200 feet, while near Rhinog-fawr the Cambrian grits exposed at the surface attain a thickness of about 6,300 feet.‡

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* Map 75 N.E., and Section, sheet No. 28, at Corsgoch, line 4.
† Map 75 N.E. and S.E., and Section, sheet 29, line 1. *See also* page 18.
‡ Section, sheet 37, lines 1 and 2.

Either, therefore, lower beds rise to the surface in that district, or else the grits and conglomerates rapidly thin out northwards. The last supposition is most probable, for not only are the same slaty bands seemingly characteristic of the whole of the lower part of the anticlinal curve from near Cefn Cam to Trawsfynydd, but it will subsequently be seen that still further north, near the Menai Straits, the uppermost Cambrian grits resting on purple slates do not attain more than a fourth part of their thickness near Trawsfynydd.

Porphyry and Greenstone.—Intruded amongst the lower beds are masses of porphyry, formed of small granular crystals of quartz, set in a compact blue felspathic base, like that afterwards to be described in connexion with similar rocks at Llanberis. Two of these lie in the district of Crawcwell, a few miles south-west of Ffestiniog, the others near Hafod-gan, and on Cefn Cam still further south. The rocks in contact with them are altered, and the porphyries, like granites and others of their class, present the appearance of rocks that have cooled deep beneath the surface.

An immense number of greenstone dykes traverse these rocks. They are especially numerous in the Cambrian grits and overlying Silurian beds of Llawllech, and also to the north and north-east as far as Cefn Cam and Craig-y-ganllwyd, but towards the sea, west of the escarpment of Rhinog-fawr, the ground is much obscured by drift. On and about Llawllech the dikes more or less follow the line of strike, but elsewhere they run in all directions, and frequently at right angles to the bedding. Some of them form continuations of lodes and lines of fault, a remarkable instance of which occurs west of Tyn-y-groes. There, between Perthlwyd and Cefn-coch, a quartz lode bearing lead, which is also a fault, separates the Cambrian and Silurian strata for about three-quarters of a mile. Between Cefn-coch and Craig-y-cae it is only recognized as a vein of quartz, and from thence to the neighbourhood of Cwm Mynach-uchaf the same fissure, ranging east and west for more than a mile, has been filled with greenstone. The dykes also form a marked feature of the ridges north of Rhinog-fawr, generally running north-west and south-east, and cutting across the strike of the massive beds of greenish-coloured grits. They rarely exceed 2 miles in length, and are mostly dark coloured, and very hornblendic; but some of them, especially among the higher beds of the formation, consist of a pale grey variety, which is sometimes slightly calcareous. In several instances the dykes were found to be so strongly magnetic, that while standing on them, and making observations with the compass, its play was completely deranged, and the observed bearing misled Mr. Selwyn and myself as to our position on the map, and so strong was the power of attraction in a pointed fragment of the stone, that when brought nearly in contact with the glass of the instrument, the needle and card spun round as if under the influence of a bar of steel. A well marked example of this occurs in the dyke cited above that occupies the same fissure with the lead lode and quartz vein west of Tyn-y-groes.

CHAPTER IV.

GENERAL DISTRIBUTION OF THE LINGULA FLAGS AND IGNEOUS ROCKS OF MERIONETHSHIRE.—LINGULA FLAGS NORTH OF THE RIVER MAWDDACH.

General Description.—Lingula Flags and Tremadoc Slate.— The Cambrian grits occupying the oval tract described in last chapter* are succeeded by the Lingula flags, and these by higher Silurian rocks, which, throughout a broad horizon, are largely intermingled with igneous products, the whole circling round the Cambrian strata on the south, east, north, and north-west. Beginning on the south near Barmouth the Lingula flags occupy both banks of the estuary to Dolgelli, from whence they strike north to Ffestiniog, and then westerly to Tremadoc and Morfa Harlech. Their junction with the Cambrian rocks is well seen at Aber-rhamffroch about half a mile east of Barmouth.

There is no unconformity. On the contrary there are symptoms of a passage in a few beds well exposed on the roadside. These dip at a high angle a little to the south of east, and consist of purplish slates merging into dark blue in the higher beds which again pass into the ordinary dark blue pyritous slates, typical of the lower members of the Lingula flags over the greater part of North Wales. In spite, however, of conformity and the apparent passage, the lithological differences of the greater masses on either side of the line are well marked. This circumstance, and also that fossils are as yet unknown in these Cambrian rocks,† while there is a speedy appearance of life in the overlying blue slates, would seem to afford sufficient grounds for this stratigraphical separation, and the employment of different colours to represent it on the map.

The Lingula flags occupy most of the country between the Cambrian strata and the interbedded igneous rocks of Cader Idris, the Arans, Arenigs, and Moelwyn. Their lower part generally consists of dark blue and ferruginous slaty beds, occasionally fossilliferous.

The higher beds assume a somewhat different aspect, for though sometimes equally dark and iron-stained, yet they are generally lighter coloured and coarser grained, both as regards the general diffusion of sandy material and also in the more frequent occurrence of beds of grit. As a whole they may be described as banded flags, formed by the repetition of numerous very thin, slightly-wavy felspathic and siliceous layers, of a light bluish grey colour, and often so felspathic that fine grained portions look as if formed of spathose dust or ashes, and, indeed, between Capel Arthog and

* Sheets 59 N.E., 60 N.W., 74 S.W. and N.W., and 75 S.E and N.E.

† A closer search among the finer grained sandstones and slates may probably yield annelid impressions similar to those found in the rocks of the Longmynd, Geol. Journ. 1856-7, vol. 11, p. 246, Salter.

Penmaen,* here and there this character so predominates that the material may possibly have originated in direct or nearly direct volcanic agency. Ripple or current marks are frequent on the surface.

The commonest fossil of these beds is the shell discovered by Mr. E. Davis at Tremadoc, and after him named *Lingula Davisii* by McCoy. It is a large square species distinct from those in the overlying Llandeilo and Bala beds, and occurs plentifully in the middle and higher part of the Lingula flags, particularly on the left bank of the Mawddach, where it was detected by Professor Sedgwick, who in the year 1846 explained the identity of these beds with the Lingula flags of Tremadoc. In the same year it was found near Dolgelli by Mr. Selwyn in the woods of Garth and in the hills above Llyn Penmaen, accompanied by a crustacean, *Hymenocaris vermicauda* (Pl. 2, figs. 1 to 4). A trilobite, *Olenus micrurus* (Pl. 2), was discovered lower in these strata, by Mr. Selwyn at Cwm-Eisen, near the base of the Lingula flags, and it occurs near Dolgelli, Tremadoc, and other places. Many more trilobites occur near Tremadoc, which will be mentioned further on.

The Lingula beds of Merionethshire are in the north, near Tremadoc, overlaid by Tremadoc slate, and there and elsewhere by felspathic ashes, interstratified with slaty Llandeilo flags. Llandeilo beds also overlie the igneous rocks of Cader Idris, Moelwyn, &c. Unlike these porphyries, which lie in a well-marked horizon, the igneous rocks of the Lingula beds are discontinuous and patchy, arising from the circumstance that they principally consist of dykes and intrusive masses, chiefly of greenstone, while a few are more purely felspathic. Both kinds occupy large spaces between the estuary of the Mawddach and Cader Idris, and great intrusions of greenstone occur south of the river, where it bends to the east below the northern flanks of Rhobell Fawr, itself the greatest mass of greenstone associated with the Lingula beds. They are also very numerous between the road from Ffestiniog to Bala and a Roman grave called Bedd Porus, about 3 miles S.S.E. of Trawsfynydd.

Igneous Rocks.—The great interbedded igneous masses already adverted to constitute the loftier mountains of the district, forming the ranges of Cader Idris and Aran Mowddwy; and west of the Bala road the same rocks, repeated by a fault, run from Penmaen to Arenig (Fig. 8, p. 37, and Pl. 28, sec. 3), beyond which they spread to the eastward by Mynydd Nodol to Craig-ddu, and thence with a very irregular outline to Llyn Conwy and Moelwyn, beyond which they bend to the south-west towards Llanfrothen, on the borders of Traeth-mawr. On the south-east and south the strike of the upper boundary of these rocks sometimes displays great regularity, but further north the line is more curving, irregular, and broken by numerous faults. They consist

* Two miles west of Dolgelli.

principally of varieties of felspathic rocks, generally divisible into consolidated ashy beds and felspathic porphyritic lava. These are regularly interbedded with each other and with the Silurian slates, and from their structure, arrangement, and effects on the strata, they are to an experienced eye easily distinguishable from intrusive rocks in the ordinary sense of that term. Their greatest development is on the east and south, between the Arenigs, the Arans, and Cader Idris. Throughout these ranges south of Arenig the ashy beds chiefly lie in well-defined strata below the felspathic lavas, and almost all the non-intrusive igneous rocks of Merionethshire have been formed in that stage of the Lower Silurian period corresponding to the Llandeilo flags.

Though at first sight we might be apt to suppose that much confusion would prevail in a highly disturbed country, where igneous rocks so much abound, yet when carefully dissected the structure is found to be comparatively simple, resolving itself into certain definite slaty masses interstratified with bedded ashes and lavas, which have subsequently been complicated by contortions and faults. The published 6-inch sections prove this point, and by their aid and that of the illustrations that accompany this Memoir, I shall endeavour to make it plain.

Lingula Flags north of the Mawddach.—I shall now describe the minuter structure of the Lingula flags between the Cambrian grits of Barmouth and the estuary. The section that illustrates the country drawn in a south-east direction from Llawllech to the Bala beds near Tall-y-llyn is specially adapted for this purpose.* No. 1, Pl. 28.

On the eastern slopes of Llawllech the Cambrian rocks are composed of the usual hard and generally thick-bedded greenish grey coarse grits and conglomerates, with occasional thin interstratifications of dark blue and purplish blue slate. The grits are often very felspathic, and the grains both of felspar and quartz being frequently imperfectly angular, impart a somewhat crystalline aspect to a freshly-fractured surface of the rock.

Between Llawllech and Y-fron-heulog the section crosses the same set of beds as those that are so beautifully exposed at Aber-rhamffroch on the coast, about half a mile east of Barmouth.

Dark blue slaty Lingula flags occupy nearly the whole of the right bank of the Mawddach, between Aber-rhamffroch and Llanelltyd, the decomposition and oxidation of the iron pyrites giving a rusty tinge to the rocks and soil, and originating the name of a place (Cae-goch, or the red field) near Llanelltyd. A long synclinal tongue of these beds forms Banc-y-frain, and runs to the very summit of the ridge of Llawllech above Llynbodlyn. At this point I found small *Lingulæ*. Like the neighbouring Cambrian rocks, this tongue is intersected by a number of greenstone dykes, which run principally along the line of strike. At its south-eastern boundary the basement line turns sharply to the north-east, and from thence trends along the flanks of the hill north-west of Llanelltyd. The average dip is south-easterly, with various undulations, the nature of which, together with the arrangement of the Cambrian grits of Llawllech, will be best understood by reference to Pl. 28, No. 1, or to the Horizontal Section Sheet 26, line 2. The rocks are frequently much cleaved, the dip of the cleavage being towards the south-east and north-west, but more frequently the former, in accordance with the average dip of the strata. Its angles vary from 75° to 95°. Beyond Llanelltyd the same beds strike more northerly, following the course of the Cambrian strata, and occupying both banks of the river by Dolmelynllyn to Rhaiadr Mawddach. The red ferru-

* *See also* 6-inch Section, Sheet 26, lines 1 and 2.

ginous hue of the rocks is strikingly manifested in the cliffy hills of Penrhos opposite the little inn of Tyn-y-groes.

Near Dolmelynllyn, in the river Camlan, close above the bridge, the junction of the Cambrian and Silurian strata is clearly exposed, and as at Aber-rhamffroch, their precise limits are indefinite, but a few yards across the strike settles the matter. They dip nearly east from 40° to 60°. A greenstone dyke, cutting the Cambrian grits in the line of strike, crosses the river a little above the bridge, and the regularity of the dip is there disturbed.*

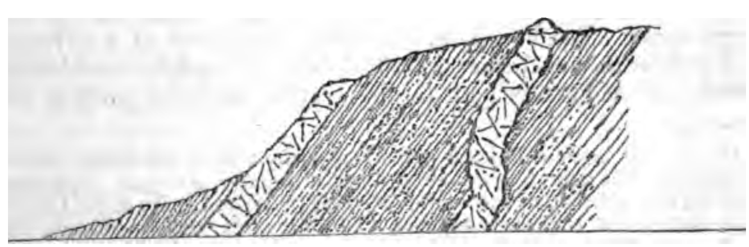
Between Barmouth and Rhaiadr Mawddach the Lingula beds are penetrated by more than 150 greenstone dykes, varying from a few yards to nearly a mile in length. A large igneous mass more than a mile in length and three-quarters of a mile in width, forms the heights of Hafod-y-fedw, between Tyn-y-groes and the third milestone on the Dolgelli road. The greater part of Moel Cynwch consists of the same rock, and also a large part of the hills between Tyn-y-Penrhos and Rhaiadr Mawddach.

When the masses are tolerably large they are occasionally columnar, the columns generally lying at right angles to the inclination of the dykes. Many of them are imperfectly crystallized and light coloured, owing sometimes to the presence of a considerable proportion of felspar. In many others their character is somewhat peculiar, in so far that instead of being principally constituted of ordinary dark green hornblende, they chiefly contain a pearl-grey variety, and almost all of them are so calcareous that they effervesce briskly with acids.

Unlike the majority of the dykes that pierce the neighbouring Cambrian grits, those in the Lingula beds show a general tendency to run in the line of strike, (notwithstanding that in many cases they pass distinctly across it,) and it is not unlikely that this may arise from the circumstance that the massive Cambrian strata are much jointed, and were fractured irregularly when the formations were disturbed; whereas in the softer and more yielding Lingula beds the intruded matter was apt to insinuate itself between the lines of bedding.

On the sides of the hills the dykes in the Lingula beds frequently rise in broad flat surfaces, dipping at high angles in conformity with the inclination of the strata, in the manner shown in the accompanying diagram in Dyke No. 1.

Fig. 1.



Hence, when beginning the examination of the country, it was supposed that these were beds of igneous matter spread contemporaneously with the deposition of the mud and sand now forming the lower beds of the Lingula flags.† This position, however, became untenable when it was observed that, though the majority run in the strike of the country, they yet are apt to break athwart

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* One of the horizontal sections (Sheet 37, line 2) crosses the boundary line about 2 miles farther north, nearly half a mile south of Rhaiadr Mawddach. The same easterly dip prevails, and the rocks of the neighbourhood (which south of Moel-hafod Owen are talcose) are in part altered and otherwise affected by intrusions of greenstone.

† *See* Memoir by Messrs. Jukes and Selwyn, Geol. Journal, vol. 4, p. 300.

the beds at small angles (No. 2.) and sometimes (like the dykes in the Cambrian grits) to cut across the strike altogether. The pierced rocks are often slightly bleached and hardened at the points of contact.

CHAPTER V.

The Range of Cader Idris.

General Description.—From Dolgelli to the sea near Barmouth, with various undulations, the general dip of all the beds is south and south-easterly, at angles averaging from 40° to 60°; and from the Cambrian rocks on the right to within a mile inland of the left bank of the estuary the section seems to maintain an unbroken ascending order. Eventually the rocks plunge beneath the igneous masses that form the range of Cader Idris (Pl. 28, Fig. 1.)* As on the opposite bank of the estuary, Greenstone dykes, more or less intruded between the beds, are common in the line of strike.

Greenstones, &c.—Instances occur on the shores of the estuary, in Garth woods, and on and near the road between Capel Arthog and Penmaen. One of them, about 4½ miles from Dolgelli, is crossed by the section (Sheet 26, and Fig. 1, Pl. 28). It is slightly calcareous, about 400 feet thick where crossed by the section, and, like others of its class, it slightly alters the beds for a few inches from the junction on either side, thus, even while partaking of the average dip of the beds, affording good evidence of its intrusive character.

These greenstones interfere but little with the run of the greater masses of strata. But in the higher parts of the series, around Dolgelli, and far beyond to the north-east and north, the igneous rocks in great part differ from the dykes in the Cambrian rocks and Lower Lingula flags, in so far that the greenstones are generally on a greater scale and run in long continuous lines over large areas. Besides these, felspathic porphyries of a type not met with in the area before described, occupy, across a considerable width, the major part both of the surface and solid body of the country.

On the hill between Dolgelli and Aberdysynni † there are several lines of greenstone. The largest, near Capel Arthog, is five miles in length. In general they dip east, south-east, and south, following the curved strike of the Lingula flags with which they are associated. They are often very hornblendic and highly crystalline, especially on the hills overlooking Capel Arthog. Were it not that they sometimes slightly cut across the strike and bifurcate, and also that they alter the slaty flags alike at their upper and lower margins, they might on a cursory observation readily be mistaken for contemporaneous lava-beds, and the same mistake might be made with others of their kind throughout the whole of the igneous districts of North Wales. Four lines of greenstone occur within a mile of the coast between Llwyngwril‡ and Aberdysynni. The alteration of the beds in contact with them is well shown on the hills immediately north of the mouth of the Dysynni, where parts of the Lingula flags are bleached and porcelanic, their high easterly dip, especially above Tal-y-cerrig, remaining perfectly apparent.

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* *See also* Section 26, lines 1 and 2.

† On the coast, 9 miles south of Barmouth.

‡ Near the coast, 4 miles south of Barmouth.

The general arrangement of the greenstones on the hills south of the Mawddach is well shown where the section crosses by Llyn-yr-Wylfa between 3 or 4 miles W.S.W. of Dolgelli (Pl. 28, No. 1, and Section 26, line 2). They are there represented dipping south-east, and at the same time cutting the strata somewhat obliquely. They are respectively about 100 feet, 150 feet, and 300 feet thick, and the upper bands are joined beneath, it being inferred that this takes place at no great depth, seeing that both branches unite at the surface a little further to the south-east.

Between Llyn-creigenen and Gelli-lwyd-fawr (two miles south-west of Dolgelli) there is a mass of felspathic trap slightly speckled with hornblende. It weathers yellow, but its fresh fracture is blue. A glance at the map shows that it lies somewhat obliquely to the actual strike of the country. Its relation to the other rocks east of Llyn-yr-Wylfa is expressed in Pl. 28, fig. 1, *F*,* and the general inclination there indicated is well seen in the cliffs above Llyn-creigenen. Like many of the greater masses of erupted matter of a deep-seated type, it has not been injected in the form of a boss, nor yet into a mere elongated ragged fracture, but, like the neighbouring greenstones, has risen towards the surface more or less between the beds, seeking in these lines of weakness a vent at some point since removed by denudation, before those latter disturbances occurred that threw both stratified and igneous rocks into their present curved and inclined positions long after the local volcanic irruptions of Lower Silurian date had ceased. At its north-east extremity it is surrounded by slaty Lingula flags. Gradually cutting its way into higher beds as it passes to the south-west, it breaks through and across long lines of greenstone and bedded volcanic ashes.

Felspathic porphyries, Ashes, &c.—In ascending order the Lingula flags cease some distance below the interbedded igneous series of Merionethshire, being sometimes overlaid by Tremadoc slates, or by the equivalents of the Lower Llandeilo flags. On this horizon they may be traced northward by Ffestiniog and Tremadoc, although lithologically it is not easy to draw a boundary line between them and the Tremadoc and underlying Lingula beds.

The Lingula flags on the south side of the estuary are intermingled with bands of dark earthy and very pyritous slate, somewhat similar to those on the opposite shore, and these chiefly occur in the higher part of the series, and afford an inferior roofing slate that has been quarried, often with little profit all round the anticlinal boss of Merionethshire. The minute interstratifications of siliceous and more felspathic and aluminous matter in the banded beds seem to have debarred the development of a close and regular cleavage, and the decomposition of the iron pyrites, in which they abound, causes the laminæ to scale off, and injures the quality of the slate.

The ashy beds of Cader Idris and other areas are of great extent and thickness, and play an important part in the igneous series. On the horizon of the Llandeilo flags they begin on a small scale on the south-west, and, sometimes interrupted, extend from the neighbourhood of Llanegryn (11 miles south-west of Dolgelli) round the south-east, east, and north of the Merionethshire anticlinal curve. For the most part they are associated with contemporaneously bedded† felspathic lavas, and the presence of the ashes in mapping lends great aid in the separation of the lava-flows from occasional intrusive felspathic masses, similar or identical with them in lithological structure. In many other

* Or in Section 26, line 2.

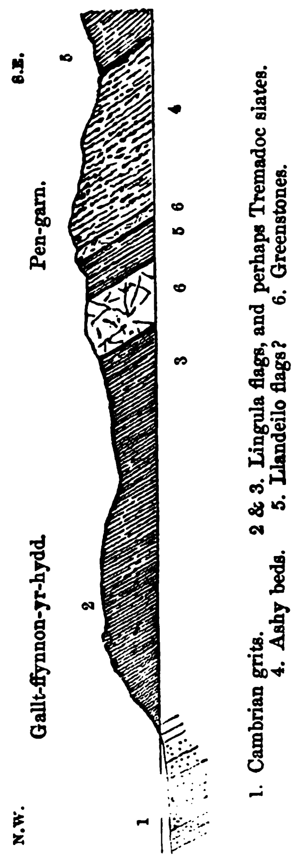
† Used in the sense of lava-flows, contemporaneous with the formation of the Lower Silurian marine strata among which they lie. The proof that the rocks termed ashes are so, is necessarily deferred till they have been described more at length.

points besides, the working out the solid geology of the lower igneous series of North Wales materially depends on the distribution of the volcanic ashes.

Less than a mile north-east of Llanegryn they consist of two sets of beds separated for the space of about 2½ miles by an interstratified band of slate. The ashy beds then coalesce, either by the thinning out of the slate to the north, or more probably by the gradual passage of that rock into ashes, owing to the admixture of volcanic material, for the boundary lines are not always definite. The following diagram will explain their arrangement.

Fig. 2.

SECTION FROM THE SEA OVER PEN-GARN AT THE MOUTH OF THE ESTUARY, SOUTH SIDE.



The rock (No. 4) consists of very calcareous brown and green sandy felspathic ashes. Further south there is a small band of greenstone on its east side, near Allt-lwyd, and another more than 3 miles long (No. 6), which, north of Pen-y-Crûg, skirts the ash on the west, separating it from the slaty beds below. It then cuts across the strike of the ashy beds by degrees, and terminates against the felspathic trap of Llyn Creigenen.

Under the ashes the rocks of Gallt-ffynnon-yr-hydd * are low in the Lingula series (No. 2), and taking this in connexion with the strike of the junction beds at Barmouth, there can be no doubt that nearly the whole thickness of the Lingula flags is comprised in the space between the larger greenstone dyke and the sea, and unless the flags be prolonged beneath the sea by undulation, the Cambrian grits (No. 1) must form the bed of the sea immediately west of the cliff, in the manner shown in the diagram No. 2. Possibly the sunken reef of Sarn-y-bwch, opposite Aber-Dysynni, may indicate the continuation of the Cambrian rocks, since the strike continues in that direction. Further south it is needless to speculate, for the whole is modified by the Bala fault that probably passes through Tal-y-llyn, down the valley of Afon-felindre to the sea. It is a downthrow on the north-west. South of this fault, on the hills between Aber-Dysynni and the Dovey, the strike becomes much more easterly, and higher beds by degrees come in. The probabilities, therefore, are that beyond this point the outcrop of the Cambrian rocks may lie far out at sea.

At Ffordd-ddu, nearly 2 miles south of Capel Arthog, the upper boundary of the ashes crosses the road. An unusually black slate (probably belonging to the Llandeilo flags) overlies it, whence the name of Ffordd-ddu, or the black road. From thence it strikes east towards the third milestone, near which it is cut off by a branching mass of greenstone and a fault, that passes from this point by Dolgelli to the sixth milestone on the Bala road. Not only has this part of the ashes been penetrated by branching greenstones, but the felspathic rock already described cuts across the ashes north-east of Llyn Creigenen, also

* 2½ miles south of Barmouth.

probably indicating the prior origin of these tuffas to the intrusion of this particular mass. At the point crossed by the section* the fault mentioned above is a downthrow on the north-west of about 2,000 feet. On its south side is an area occupied by felspathic porphyry of about a mile in length, *F*, Fig. 1, Pl. 28. The same ashes *f′* lie above it, and it therefore is likely that the two felspathic masses were once united and are repeated by the fault, even although, being intrusive, they occupy slightly different horizons. How the fault ends on the south-west is uncertain, but above the bulk of the ashes there is a large mass of rough felspathic porphyry, which breaks across the strike of the beds on the cliffs on either side of Llyn Cyri, and spreads by Mynydd Pennant over a broad tract towards Llanfihangel-y-Pennant, where it branches to the east, partly interrupted by a north and south fault that throws the rocks down on the west between Rhiw-gyriedydd and Tyrau-mawr.†

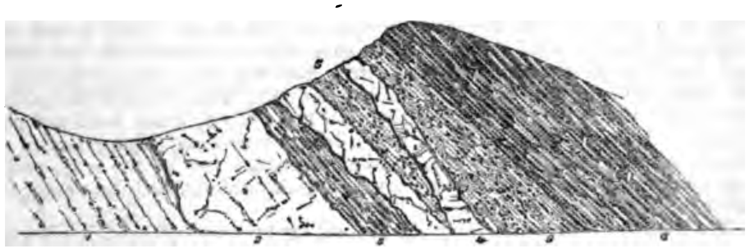
Cader Idris.—If we examine the section on both sides of the fault that runs north about 2 miles west of the summit of Cader Idris,‡ we shall find that in spite of intrusive rocks the masses nearly assume the general order shown in the following diagram :—

Fig. 3.

CADER IDRIS.

Rhiw-gyriedydd.

N. S.



1. Calcareous and felspathic ash (Llandeilo).
2. Felspar porphyry.
3. Llandeilo beds.
4. Greenstone, instrusive, and branching.
5. Felspathic and calcareous ash.
6. Llandeilo flags (black slate). §

East of the fault the porphyry lies with great regularity on the calcareous ashes, which here strike east and west beneath the northern cliffs of Cader Idris. The ashy beds are about 3,300 feet thick. Their position will be understood by reference to *f′*, Pl. 28, No. 1, or to the horizontal section, sheet 26, line 3, where they are described by Mr. Selwyn as consisting of "vesicular, " calcareous, and felspathic ashes, interstratified with arenaceous and felspathic " slaty beds, generally more or less ashy, and sometimes conglomeratic and " brecciated." Where they are crossed by this section greenstones *g* are intruded into them, partaking of the dip of the country, yet partly cutting across the beds.

Within 100 feet of the upper boundary of the ashes is a band of blue slate, from 80 to 100 feet thick, which passes eastward in the same stratigraphical position as far as the Dolgelli and Machynlleth road. It is succeeded by 50 or 60 feet of highly porphyritic hard felspathic ash, above which is an enormous mass of felspar porphyry *f*, often columnar. Beautifully symmetrical columns strew the slopes of Cyfrwy, and give a special character to the cliffs. They are often used for gate posts. On the north slopes of Cader Idris the porphyry is jointed, espe-

* *See* Map 59 N.E., ¼ of a mile south-west of the third milestone Section Sheet 26, line 2, near the Dolgelli and Towyn roads, and Diagram No. 1, Pl. 28.

† On the Cader Idris range, 4 miles south-west of Dolgelli.

‡ *See* the 1-inch map west of the C. of Cader Idris.

§ This has been too much speckled in the engraving. The lines ought to be straight and flaggy looking.

cially on Mynydd Mawr, where the joints have all the regularity that they sometimes assume in granitic masses. The broken ground at its base is strewn with blocks that have fallen from the cliff, some of which in dimensions may be compared to small houses. These lie in large, irregular mounds, and probably owe this arrangement to the time when the hollow between Cader Idris and Mynydd-Gader was packed with ice. The tinkling sound of flowing water is heard beneath the stones, and the smaller earth having been removed by it, the larger masses tumbled in, and the irregularity of the surface has been thereby increased. The parent rock is slightly hornblendic, and is here about 1,700 feet in thickness. Except where broken by faults, the same great mass is continuous from hence along the long ridges to the north end of the range of Aran Mowddwy. Resting on this porphyry, south of Cyfrwy and Llyn-y-Gader, are beds of blue slate *s*, Fig. 1, Pl. 28, of 200 or 300 feet in thickness. These are succeeded by a band of greenstone *g*, about 250 feet thick, which, though seemingly interstratified, is certainly not contemporaneous, seeing that it branches near Tyrau-Mawr, and on the north cliff of Cader Idris it alters the slate both above and below into a species of porcelanite.

In ascending order, where crossed by the section (No. 1, Pl. 23), the greenstone is succeeded, first, by 60 or 70 feet of blue slate; secondly, by 100 feet of hard porphyritic felspathic ash *f′*; then by 20 or 30 feet of blue slate, on which rests a thick mass of vesicular and largely botryoidal greenstone *g*. On the surface the vesicles are often empty, but in the body of the rock they are filled either with quartz or carbonate of lime, and sometimes with both, as if one were removed and replaced by the other. The kernels are frequently coated with chlorite. The greenstone is about 500 feet thick, and forming the summit of Cader Idris, stretches down the south side of the mountain, on the dark and broken mounds that roughen the slopes above Llyn Cau. The slate in contact with it is altered, being hard and porcelanic. On the northern cliff of Cadir Idris, overlooking Llyn-y-Gader, all these traps and slates may be seen bending along the face of the crag, and a bold climber may descend in the gullies, and walking along the ledges mark the effect of the traps on the associated slates.

The bottom of Llyn Cau, and the ground further east and west, is occupied by about 900 feet of blue slate *s′*, resting on the greenstone. It is sparingly intermingled with thin bands of felspathic ashes, and sometimes the true slaty matrix contains small detached felspar crystals, entire or fragmentary. On the south side of the lake, resting on this slate, there again occurs a mass of felspar porphyry *f* about 1,500 feet thick. It is sometimes rudely columnar, and has been described by Mr. Selwyn as a "grey and brown slaggy felspar trap, often "porphyritic, with small crystals of glassy felspar."* Its general character resembles that on the north slope of Cader Idris.

A cursory examination of the section alone would lead to the conclusion that these great bands of porphyry are essentially distinct, and that following as they do the southerly pitch of the strata, they represent two enormously thick lava beds that flowed abroad on the muddy or ashy sea bottoms of the time, being separated by a long period represented by the accumulation of more than 2,000 feet of intervening stratified and igneous rocks. Such however is not the case. Interbedded as they appear, they are probably intrusive, owing to the circumstance (*see* Map 59 N.E.) that they break across the strike and unite on the west at Twll-yr-ogof, and on the east by the brook that runs from Llyn Cau in the direction of Minffordd, thus at both ends cutting out the stratified rocks that separate them in the intervening space.

It is a striking fact that none of the igneous rocks from the Mawddach to Tal-y-llyn, except the ashes, are certainly contemporaneous. However regular their dip, all the rest seem to be intrusive. Of the 4,000 feet of igneous rocks that dip southerly from the base of the Llyn-y-gader trap, not more than about 400 feet of ashes were contemporaneously formed with the slates amid which they lie. The rest are of somewhat later date. This will be subsequently explained. In the meantime it will be well to repeat the remark already applied to the trap of Llyn Creigenen, that, at least over what is now the *western* part of Cader

* For an explanation of the term slaggy, as here used, *see* p. 123.

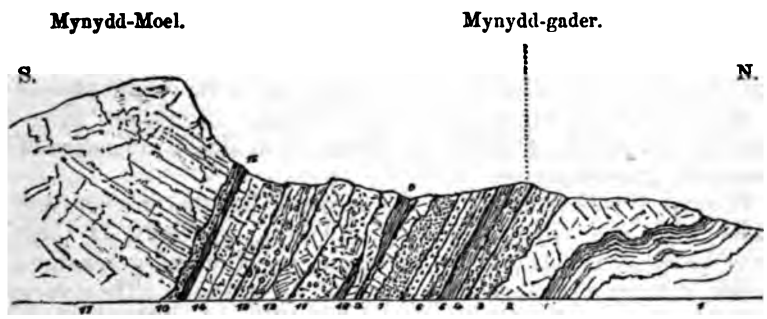
Idris, all these great felspathic masses seem to have been injected more or less between the beds, and like the greenstones have since been disturbed by those later forces that threw into great curves the whole of the rocks of the country.

West, south, and east of Dolgelli patches of greenstone have been protruded amid the strata, the irregular forms of the igneous rocks being in some degree due to the contortions of the Lingula flags among which they lie. Partly in the town and partly to the south-west of Dolgelli there is a boss of greenstone, largely crystalline on the Towyn road, but decomposed, soft, and earthy on the surface by the banks of the brook below Pandy.

In no part of this country can a clearer idea be obtained of the nature of its rocks and of their order of superposition than on the space that lies between the ridges of Mynydd-gader and Mynydd-Moel, for there slates, ashes, and felspathic porphyries lie in regular order, unbroken by faults and uncomplicated by contortion. As it is typical of the whole area between Cader Idris and Arenig, I shall, with the help of diagram fig. 4, attempt to explain its details.

Fig. 4.

Section between Mynydd-Moel and Mynydd-Gader on the North Side of Cader Idris.

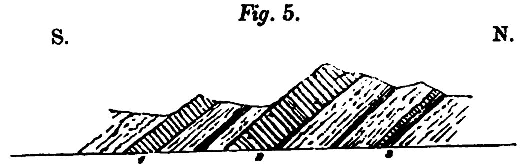


Between Dolgelli and Cader Idris the Lingula flags are much disturbed (No. 1). Under the greenstone (No. 2), there is a bed of very black carbonaceous shale, once mistaken for and fruitlessly worked as plumbago. The greenstone breaks somewhat irregularly through the slaty and ashy beds, thrusting short veins into the strata, which are hard and flinty in its immediate vicinity. No. 3 is a fine felspathic bedded breccia which seems as if it had been porcelanised by the greenstone. Rude concretionary agates sometimes form an integral part of its mass. It is succeeded by a felspathic conglomerate (No. 4) seemingly unaltered. A slaty band (No. 5) rests on this, above which are beds (No. 6) of felspathic ash, conglomerate, and stratified amygdaloid, mingled with irregular beds of slate. No. 7 is composed of felspathic ash beds, fine conglomerate, lapilli and volcanic sand, intermingled with thin siliceous layers. Nos. 8 and 10 are greenstones enclosing dark slate and ashy beds No. 9. No. 11 is composed of calcareous ash and rubbly vesicular

conglomerate. No. 12 is a fourth mass of intrusive greenstone, above which are beds of calcareous ash and conglomerate No. 14. These pass into a vesicular ashy conglomerate more than usually calcareous, and this is succeeded by a thin band of black slate (No. 15), on which rests a hard porphyritic felspathic ash (No. 16) These last are the equivalents of the two bands underlying the Llyn-y-Gader trap,* and the felspathic and often rudely columnar trap of Mynydd-Moel (No. 17) is a continuation of the intrusive mass of Mynydd Pennant, Cyfrwy and Llyn-y-Gader. The calcareous ashes and conglomerates below the trap of Mynydd-Moel are about 2,000 feet thick, and the more felspathic ashes and conglomerates, mingled with slaty bands that lie between the calcareous ashes and the greenstone of Mynydd-gader, about 1,500 feet thick. These thicknesses nearly correspond with those of the same rocks as shown in Section No. 1, Pl. 28.† The whole of these bedded igneous rocks and slaty strata above the lower part of No. 1 (fig. 4), belong possibly partly to the Tremadoc beds, but chiefly to the Llandeilo series, and a mile to the south-east of Mynydd-Moel black Llandeilo slates rest on the trap. There are many similar sections in Merionethshire, and I therefore draw attention to this one at an early stage of the Memoir that the reader may understand the numerous alternations of different kinds of volcanic matter (interstratified with beds of slate) that make up an entire thickness of more than 3,000 feet; the result of many volcanic eruptions probably far apart in time, that ejected clouds of dust, sand, and stones to be spread abroad by the sea and piled upon each other in slow succession, intermingled with bands of muddy sediment (now slate) indicative of periods of greater repose.

Through the whole length of the upland valley that lies between Cader Idris and Mynydd-gader, the ashes, especially in their lower beds, are penetrated by numerous injections of greenstone similar to those indicated in the above description. They vary from a few yards to about a mile in length. So intimately are they intermingled with the slates and ashes that it is difficult in mapping to separate them, and quite impossible to represent them accurately on the 1-inch scale of map, for the smaller bands are often only a few feet thick. The larger ones are, however, sometimes several hundreds of feet in thickness, and all of them run for the most part between the beds either in or nearly in the line of strike. They are frequently columnar, the columns lying at right angles to the dip, as shown at 1, 2, 3, in the following diagram:—

Fig. 5.



* Section, Sheet 26, and Pl. 28, No. 1.

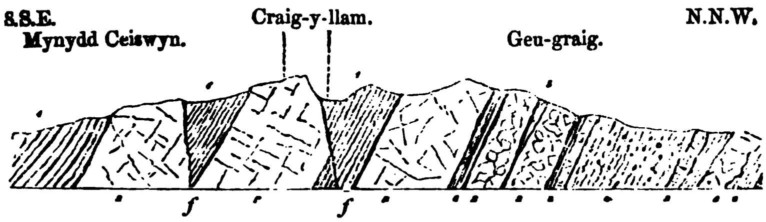
† *See also* Sheet 26.

The flat ends of the columns, where once they abutted on the superincumbent strata, being exposed by denudation, often present a beautifully tesselated appearance.

One additional diagram may suffice to explain the structure of Cader Idris. It represents the general arrangement of the rocks on a N.N.W. line, between Fron-fraith, about 4 miles S.S.E. of Dolgelli, to a point within 2 miles of the town, and is partly given to show the repetition of the igneous rocks by faults, one of which, as it ranges north-east towards Bala, produces a great effect on the physical geography of the country.

Fig. 6.

SECTION FROM MYNYDD-CEISWYN TO GEU-GRAIG NEAR DOLGELLI.



1. Llandeilo flags.
2. Felspar porphyry.
3. Greenstone.
4. Felspathic ashes, &c.
5 and 6. Slaty bands in No. 4.

f. Faults.

In this diagram the strata No. 1 represents the black slates supposed to be Llandeilo flags, No. 2 the felspathic porphyry of Mynydd Ceiswyn, Craig-y-llam and Geu-graig. These igneous masses are equivalents, being repeated by two large faults (*f*). The rocks marked No. 3 are greenstones intruded between the beds. No. 4 represents in their usual position beneath the porphyry the calcareous and felspathic ashes previously described, No. 5 beds of slate intermingled with these igneous strata, and No. 6 some upper beds, probably of the Lower Llandeilo flags. There is no marked difference between the rocks on this line and those farther west; the slates are the same. The felspar porphyry, No. 1, is perhaps less massive looking; that is to say, it possesses less of the character that belongs to the more deep-seated igneous rocks, for it is less crystalline than the columnar and jointed masses of Cyfrwy and Mynydd-Moel, and specks of hornblende are more rare. The ashes are still conglomeratic, calcareous, and often vesicular, and a highly porphyritic blue band lies at the top, identical with that which underlies the porphyry of Mynydd-Moel. Though porphyritic it is readily distinguishable from a genuine crystalline porphyry, for its crystals look not as if separated from the matrix during the process of cooling, but rather as if they had been showered out along with and mechanically embedded in an ashy paste. They are, besides, often broken, and pebble-like fragments and slaty flakes occur in the enveloping spathose matter. The greenstones of Geu-graig (*see* diagram) have a rubbly look, as if the mass in cooling had arranged itself in large spheroids, which occasionally show a tendency to angularity at the sides, approaching to the columnar structure. On the whole, they strongly resemble the rock that forms the crest of Cader Idris. The ashes are of much the same thickness as in the previously described sections. The felspathic trap is about 1,800 feet thick, only a little thicker than the Llyn-y-Gader division of the same rock on Cader Idris.

Of the two faults shown in the diagram, the more westerly, which passes through Llyn Trigraienyn, is a continuation of the great Bala fault, and the other, though apparently of nearly equal magnitude, is lost on the south-west among the slates. On the north-east it perhaps ends against the small north-west dislocation that lies between Waun-oer and Cribin-fawr.*

* One mile and a half south of the fifth milestone on the road from Dolgelli to Dinas Mowddwy.

North-east of Geu-graig for several square miles the structure of the country is exceedingly complicated by faults, greenstones, and contortion of the rocks; the whole being rendered yet more obscure by the deep drift that covers many of the valleys and slopes round Caerynwch and the Cross Foxes.*

The Geu-graig greenstone spreads out towards the north, because of the gradual decrease of its inclination. It has been stated that a band of slate overlies it (diagram fig. 6). Both greenstone and slate are cut off near Geu-graig by an east and west fault, which, being a downthrow on the south, has thrown the Geu-graig rocks forward from Hafod-oer above the turnpike road. This result is assisted by the western downthrow of the great Bala fault, which, it is inferred, here passes by the turnpike road underneath the drift on its passage to the valley of Tal-y-llyn. At Geu-graig and Hafod-oer, the sections are, in fact, identical, and consist in descending order of felspar porphyry, slate, greenstone, and true felspathic ashes.

Within half a mile north-east of Hafod-oer the greenstone is affected by two small dislocations. These coalesce by Ty'n-rhos and resolve themselves into one fault, which passes across Pen-bwlch-coch from east to west, and throws down the ashes against the greenstones that lie about their base between the Gwen-graig and Pen-bwlch-coch faults. These greenstones, with others of their class in Merionethshire and Caernarvonshire, though manifestly injected, are, like the bedded felspathic rocks, invariably affected by the contortions of the rocks and the faults of the district, proving the injection of the greenstone before these disturbances took place.

The gradual passage of the same greenstone from one stratigraphical horizon to another is well shown in the triangular space that is enclosed between the Bala, Dolgelli, and Pen-bwlch-coch faults.† Immediately north of the last, this greenstone passes somewhat obliquely to the strike, from the slaty beds below entirely across the ashes, and intrudes itself into the overlying felspar porphyry, which is here repeated by the Bala fault, and forms a long narrow band between the neighbourhood of the sixth milestone on the Bala road and that part of Foelseudian which lies 3½ miles east of Dolgelli.‡

Another large and irregularly branching mass of greenstone lies between Tyddyn Mawr§ and Pen-ar-Wnion.‖ On the whole, the Tremadoc and Lingula flags lie beneath it, and three times in its windings it abuts on the Dolgelli fault, which here, by a north-western downthrow, again brings in the ashy beds on the south and east of Moel Offrwm.¶

Near Dinas Mowddwy a north-west fault passes up the valley of Afon Geryst to a place called Esgeiriau, where it joins the Bala fault near the sixth milestone previously mentioned.** The rocks dip easterly, and are thrown down on the south-west from 2,000 to 3,000 feet, causing the felspathic trap to abut against the ashes on the north slope of Penbryn-fforchog. West of the Dinas Mowddwy fault, near Esgeiriau, the Tremadoc slates and Lingula flags dip south-east at angles of 35° and 40°. Above them lie the ashes, and these are succeeded by the same felspar porphyry that forms the ridge of Cader Idris, on which rests the dark blue or black Llandeilo slates that run all along the strike between the south slopes of Cader Idris and the eastern flanks of the Arans. The same porphyry also forms the centre of an anticlinal axis on the turnpike road, about 2 miles north-west of Dinas Mowddwy. (fig. 7, p. 35.) Its eastern continuation is cut off by the fault, and the slate having been removed by denudation from the crown of the arch, the igneous rock is exposed in the valley of Afon Geryst.

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* East of Dolgelli from 2 to 3 miles.

† The Dolgelli fault passes through Dolgelli to the sixth milestone on the Bala road. It there joins a great branch of the Bala fault which runs north by Y-Dduallt and Moel-llyfn-nant to the Bala and Ffestiniog road near Tai-hirion. The Bala fault runs from the sea near Aber Dysynni to the edge of the New Red Sandstone near Hope, a length of about 60 miles.

‡ Maps 59 N.E. and 75 S.E.

§ One mile and a half E.S.E. from Dolgelli.

‖ Above the Bala road 4½ miles north-east of Dolgelli.

¶ Two miles and a half N.N.E. of Dolgelli.

** Maps 59 N.E., 60 N.W., 74 S.W., and 75 S.E.

CHAPTER VI.

The Range of the Arans—The Bala Fault.

General Description.—Aran Mowddwy, &c.—The whole of the rocks and of the Aran range dip a little south of east at angles varying from 40° to 70°, as shown in the section No. 3, Pl. 28.*

The solid rock of the Arans much resembles that of Cader Idris, being felspathic, somewhat harsh to the touch, often porphyritic, sometimes columnar, and by the occasional sparing development of hornblende, sometimes assuming the character of a hornblendic felspar-porphyry or very felspathic greenstone; it is about 2,500 feet thick. Two principal bands of slate occur in it on the western slopes, and others of a similar kind but shorter are found further south. The whole range, therefore, is not to be looked upon as one mighty lava-flow, but rather as the result of successive outpourings from vent, some of the intervals being marked by slaty interstratifications. Where the section crosses the hill the trap is separated from the ash by one of the slaty bands, which is indurated, as if by heat, like others in the range. The dark blue slates, however, that rest on its upper edge are quite unaltered. The heat of the submarine lava current baked the muddy sea bottom over which it flowed, but had no power to alter the sediment deposited on its cooled upper surface.

The ashes *f′* that underlie the porphyry *f* resemble their equivalents near Dolgelli. South of Cwm-y-dolau (between Aran Mowddwy and Drws-y-nant) they are frequently vesicular and calcareous, like many of the beds of the Cader Idris range. North of Cwm-y-dolau they are but slightly and rarely calcareous. In general terms they may be described as consisting of a felspathic base, in which there frequently occur short patchy lenticular masses of a very coarse felspathic volcanic conglomerate containing fragments both angular and rounded, varying from the size of a pin's head to 18 or 20 inches in diameter. The rounded fragments look as if waterworn, and both these and the angular pieces are for the most part composed of felspathic porphyry containing distinct crystals of glassy felspar. The weathered surfaces of the rock best show its true character, and it then becomes apparent that much of it is composed of aggregations of broken crystals of felspar, confusedly imbedded in a hardened felspathic paste. Sometimes this structure entirely disappears in a freshly-fractured surface, but frequently even then it is apparent. This is alike characteristic of the porphyritic ashes of the Arans and Cader Idris, and may be accounted for on the supposition that broken crystals were showered out with the more finely comminuted felspathic dust, which is the chief constituent of the

* *See also* 6-inch section, Sheet 29.

matrix of the rock. Occasional thin slaty beds mingle with the ashes. The whole mass dips E.S.E. at angles of from 60° to 80°, and attains a thickness of about 3,300 feet, so that we have here probably the representatives of the calcareous ashes of Cader Idris, and of the felspathic ashes and interstratified slates of Myndd-gader, that form the lower part of the series, as shown in fig. 4. Further north, however, both the overlying porphyry and ashes thin rapidly away, for at the end of the Aran range by Moel-ddu their thicknesses have respectively decreased to about 1,100 feet. The inclination of the beds is also much less, in places not exceeding 30°.

Lingula Beds.—The description given of the Lingula beds near Dolgelli applies to those between the Arans and the Bala and Dolgelli road.* They generally consist of grey flaggy rocks, sometimes gritty, but mostly slaty, and often pyritous, and here and there they are interstratified with bands of dark blue and black slate. Between the great Bala fault which runs parallel with the turnpike road and the bottom of the ashes they dip steadily eastward, at angles between 45° and 70°, their total thickness being about 6,000 feet; a thickness gradually disappearing on the north, in consequence of the strike of the country carrying higher beds against the igneous rocks on the west or downcast side of the Bala fault.

In the neighbourhood of Afon-Cwm-ochr numerous greenstone bands have been intruded, among the Lingula beds and the ashes; but north-east of the felspathic trap of Y-Foel-ddu these are comparatively rare.

West of Aran Mowddwy the igneous boss of Y-Foel-ddu touches the ashy beds at Y-Gadfa, and stretches north towards the lower part of Cwm-y-dolau. It thus passes across the Lingula beds, nearly from top to bottom, in a broad mass, the greatest length of which runs nearly at right angles to the strike of the flags. Lithologically, it resembles the felspathic traps of the Arans and Cader Idris, being for the most part a compact blue rock, occasionally vesicular, weathering white or pale yellow. Its form shows its intrusive character, and wherever the Lingula flags are seen in contact with it, they are bleached and porcelanic for a few inches from the line of junction.

Detailed Sections.—Taken as a whole, the Aran section is the simplest of this part of the series in Wales, for all the Lower Silurian strata possess a steady unbroken easterly dip across the series of the Bala and Llandeilo beds,† over the felspathic porphyry and volcanic ashes, and from thence far down towards the base of the Lingula flags. In its lower members it is more easily made out than the corresponding section between the Mawddach and Cader Idris,‡ owing to the general absence north of Cwm-y-dolau of masses of *intrusive* felspathic porphyry and of injected greenstones, which, nearer Dolgelli, induce such excessive complication in the details of the Lingula flags and the igneous rocks above them; for, besides being of all shapes

* The existence of the Lower Llandeilo flags has not yet been proved immediately under the ashes of the Arans, but as they occur west of the great Bala fault (see p. 37) there can be little doubt that they also occur above the Lingula flags of the Aran country.

† *See* Section, Sheet 29, and Pl. 28, No. 3.

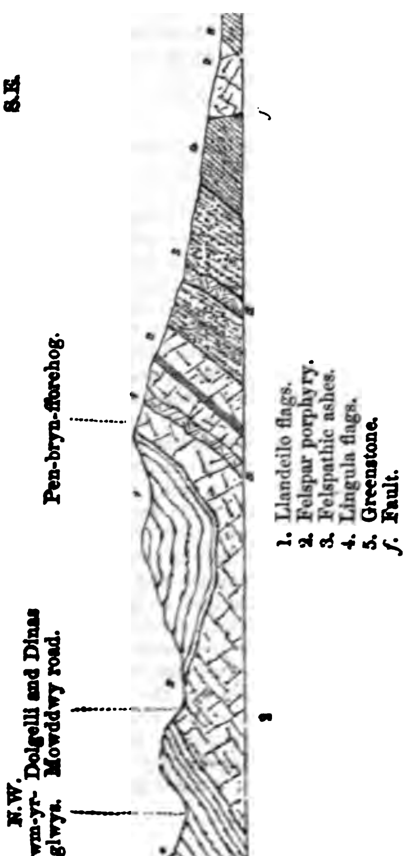
‡ Section 26, lines 2 and 3, and Pl. 28, No. 1.

and sizes, and occurring at all horizons between the Cambrian rocks and the base of the Llandeilo beds, their presence being as it were accidental, it becomes no easy matter to unravel in the field the geological intricacies of a mountainous country where felspathic porphyries, ashes, and greenstones are often externally so much alike that the most practised eye can scarce distinguish them before the application of the hammer. But, notwithstanding these accidental complications, the foregoing descriptions make it evident that between the top of the Cambrian rocks north of the Mawddach and the Bala and Llandeilo beds that rest on the Cader Idris range, the general Silurian section perfectly resembles that of Aran Mowddwy, as low as where in the latter the Lingula beds are cut off by the Bala fault.

South of the Arans between Nant Cwm-yr-Eglwys* and the neighbourhood of Esgeiriau the rocks lie nearly as shown in the following diagram.

Fig. 7.

Section North-west of Dinas Mowddwy.



Nos. 1 and 2 represent the supposed Llandeilo flags and felspar porphyry curving in anticlinal and synclinal axes between Nant-cwm-yr-Eglwys and the north-western slopes of Pen-bryn-fforchog. Beneath the porphyry lie the felspathic ashes, No. 3; these are succeeded by the Lingula flags, and possibly Tremadoc slates, No. 4, which long before we reach their base are cut off by the Bala fault *f*, again bringing in the felspar porphyry and ashes (Nos. 2 and 3) by a downthrow on the north-west of about 7,000 feet. Greenstones (No. 5), dipping with the rocks, pierce them in two places.

North-east of the Dinas Mowddwy fault the rocks are for about a mile slightly complicated by greenstones and several minor dislocations.

The Bala Fault.—I shall now notice some of the effects produced by the great Bala fault on the area between the Aran range and the Bala and Dolgelli road.

The effect of this fault further south-west has already been shown in diagram No. 6, where, between Craig-y-llam and Geu-graig, the traps have been thrown down on the north-west probably about 4,000 feet. In that neighbourhood, a little beyond the turnpike gate, the fault passes into the ashes, and being a downthrow on the north-west, the same beds are repeated, which, if the mapping be correct, sufficiently

* One mile and a half W.N.W. of Dinas Mowddwy.

accounts for the colouring on the map of the broad drift-covered tract presumed to be occupied by ash in the country round the inn called the Cross Foxes.

Still further north-east, it has been shown (fig. 7), that the felspathic porphyry and ashes of Pen-bryn-fforchog have been thrown againt the Lingula beds by the fault *f*, and that the amount of this throw is probably near 6,000 feet. When followed along its strike, this porphyry leads directly to that of Wenallt, Careg-Aderyn, and Penmaen.*

These hills form a steep escarpment along the Bala road, and the Bala fault runs at their base as far as Pant-gwyn,† beyond which the line between the igneous rocks and the true *overlying* black slates and shales strikes nearly due north along the eastern flank of Arenig. From Pant-gwyn the fault passes into Bala lake, cutting off the whole of the rocks of the Aran range in their passage north.

At the point crossed by the section (Pl. 28, No. 3),‡ the unbroken dip of the rocks between Careg-Aderyn and Aran Mowddwy, makes it practicable very nearly to estimate the amount of downthrow by which the felstones and ashes of Aran Mowddwy have been brought to the level of Careg-Aderyn. Assuming what will afterwards be proved, that the felstone of Careg-Aderyn is the equivalent of that of Aran Mowddwy, the following are the necessary steps in the argument:—

1st. Eastward of Careg-Aderyn the rocks dip steadily east at high angles showing no symptom of an anticlinal axis. The Aran Mowddwy felstone porphyry is therefore not brought to Careg-Aderyn by a roll of the strata.

2nd. It is evident by this repetition that the Aran Mowddwy rocks once extended, before their disturbance, in unbroken continuity in that direction.

3rd. The beds between the fault and Aran Mowddwy resting conformably on each other, they have all been raised into their present inclined position together.

4th. If we restore the continuation of the separate beds between the fault and Aran Mowddwy, and make an allowance for the thinning out of felstone and ashes to the north; and if we prolong the fault upwards at its assumed angle till the lines meet, then if the porphyry in the valley correspond to that of Aran Mowddwy, the downthrow on the north-west from *a* to *b* (*see* Pl. 28, No. 3) must be from 10,000 to 11,000 feet. The angle at which the fault is drawn is hypothetical, and this, of course, modifies the amount of throw. Still, were we to reduce the inclination of the fault to the lowest possible amount, viz., to the average slope of the ground from the valley to the summit of Aran Mowddwy, it would still give a displacement of strata of at least 11,000 feet. It is by no means necessary to suppose that the whole of this enormous displacement took place at once, or even during any one of those sections of geological time that for convenience we name periods, for the aggregate amount may be the result of many slips, extending through many geological epochs. However this may be, it is nearly certain that with sufficient denudation a very little additional downthrow would have brought into the valley the uppermost beds of Cambrian grit, since more than 6,000 feet of Lingula flags are exposed between the ashes and the valley of the Wnion; and if in the Cader Idris section the estimated thickness of these beds (6,750 feet) be correct, then the Cambrian grit must lie only a few hundred feet beneath the river Wnion. Towards Bala Lake the throw becomes gradually reduced to about 5,000 or 6,000 feet. The inclination of the strata decreases, and only about 2,500 feet of the flaggy strata, and 2,200 feet of ashes and porphyry between Pant-gwyn and Pandy§ abut on the black slaty Llandeilo shales that rest on the igneous rocks of the Arenig and Penmaen range, which shales are the equivalents of the beds that overlie the felstone of Aran Mowddwy. This reduction of the throw from 13,000 to 5,500 feet is proved by comparing the section in Plate No. 28 with the west end of the following diagram, fig. 8, the ground which these lines cross being not more than from 2 to 3 miles apart.

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* Map 74 S.W., west of the Bala road.

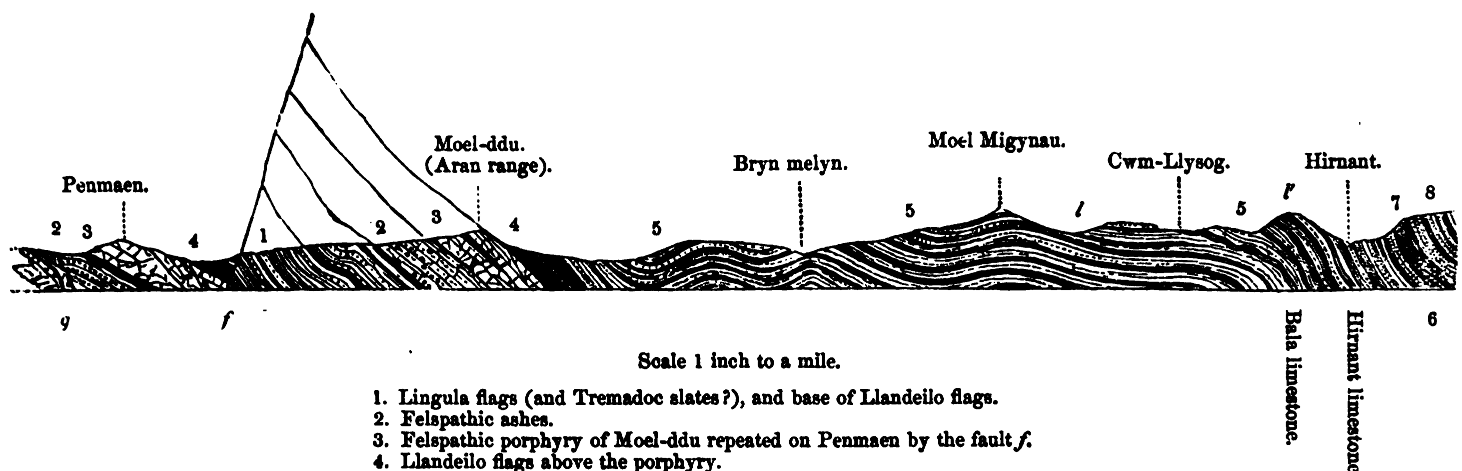
† Two miles and a half south-west of Llanuwchllyn, Map 74 S.W.

‡ *See also* 6-inch Sections, Sheet 29, lines 2 and 3.

§ About half a mile south-west of Llanuwchllyn.

Fig. 8.

SECTION ACROSS PENMAEN AND MOEL-DDU AT THE NORTH END OF THE ARAN RANGE.



Scale 1 inch to a mile.

1. Lingula flags (and Tremadoc slates?), and base of Llandeilo flags.
2. Felspathic ashes.
3. Felspathic porphyry of Moel-ddu repeated on Penmaen by the fault *f*.
4. Llandeilo flags above the porphyry.
5. Bala beds.

l. Bala limestone. *l'*. Hirnant limestone in Bala beds.

6. Lower Llandovery rocks.
7. Tarannon shale.
8. Denbighshire grits (Wenlock).

g. Greenstone.

CHAPTER VII.

Repetitions of the Rocks of the Aran Range by Faults and Curvatures of the Strata continued.—Greenstone of Rhobell-Fawr, &c.—Talcose Schists of Dol-y-Frwynog.—Copper and Gold Mines.

General Description.—A long straight valley, through which the turnpike road runs, lies between Bala Lake and Dolgelli. It has been already stated that the range of hills that bounds it on the north-west results from the repetition of the hard felstones of the Arans by the fault described at the close of last chapter. Escaping from the immediate influence of the fault at Penmaen, this range suddenly trends straight north as far as Arenig, beyond which the hills formed by the igneous rocks become broken and scattered over a wide extent of country. Near Drws-y-nant-isaf* on Careg-Aderyn and Penmaen, and northwards towards Arenig, the rock is a bluish grey felspathic porphyry, which breaks with a sharp fracture, like hornstone, and weathering pale yellow or white, often shows a brecciated and slaggy or even scoriaceous structure, which, however, on a freshly fractured surface is generally indistinguishable. The same felspathic and calcareous ashes and conglomerates that underlie the felstones of the Arans rise from under its western edge.

A mass of *upper ashes* (so called because they lie above the felspar porphyry) commence about half a mile north-east of Penmaen, and gradually increasing in thickness, soon become, on the Arenigs, of very great importance.

West of Llanuwchllyn the rocks lie in the form of an anticlinal and a synclinal axis both faulted. But for the faults, we should have on the west a simple synclinal curve, enclosing an isolated basin of slaty shales between the porphyry of Careg-llyssog and Y-Dduallt. The result of this arrangement of the rocks is a third marked range of hills, forming the heights that run between Craig-y-Benglog and the peak of Moel-llyfn-nant, made of the equivalents of the Aran felstones. Beneath it the ashes crop out a third time on the west, overlying the Lingula flags, which, with some broad undulations of the strata, spread 4 miles westward to the central boss of Cambrian grits.

Felspathic rocks and Llandeilo beds north and west of the Bala and Dolgelli road.

Westward of Drws-y-Nant-isaf the felstone is more than a mile in width, being thrown into the anticlinal curve mentioned above, one side of which, beyond Y-Wenallt and Foel Ddu, is cut off by a fault that passes northward, and crosses the Bala and Ffestiniog road a little east of Tai-hirion.† This

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* Ten miles and a half from Bala on the Dolgelli road.

† Map 75 N.E. and S.E.

anticlinal curve widens by degrees, and volcanic ashes, cut up by numerous small faults, form its centre.*

The disturbance of the rocks is here so excessive, that it becomes truly difficult to disentangle their intricacies, since, in addition to the irregular mixture of ordinary sediment and ashy matter, these are so interpenetrated by numerous thin injections of greenstone that it is almost hopeless to attempt on a one-inch scale to separate the latter from the ashes that often assume their aspect.

Following the anticlinal line to the north by Drysgol, the porphyry again closes over the ashes, and in the sharp bend the beds have snapped at Castell-carn-dochan,† and a narrow strip of upper ashes and overlying Llandeilo beds, let in between two faults, forms the ridge of Cerig-yr-eirch and the valley that runs from thence towards Dolhendre.‡

North of Cerig-yr-eirch the felspathic lava occupies a rough and rocky tract of about 2½ miles in length by 1½ in width, comprising the hills of Bryn-brâs,§ Craig-dol-fadr, Clogwyn-yr-Eglwys, and Fridd-trawscoed. The rock undulates in wavy contortions, whence its unusual breadth. On the east it is overlaid by the upper ashes, and on the north, south, and west it is bounded by faults. The south fault is one of those that cross the ridge of Cerig-yr-eirch. It is a downthrow on the south. The north fault passes about 2½ miles in a south-western direction from Moel-y-menyn.‖ The west fault passes from the neighbourhood of Careg-Llyssog northward, and joins the Tai-hirion and Y-Dduallt fault on the east slope of Moel-llyfn-nant.¶ Its throw is greatest immediately south of a hill called Cefn-glas, where the downthrow on the west probably amounts to 1,000 feet, the whole of the felstone porphyry being cut out for a quarter of a mile, so that the black Llandeilo slates and the lower ashes lie in juxtaposition. These Llandeilo beds lie in a long narrow trough, 3½ miles in length, directly south of Clogwyn-yr-Eglwys.** Except for about a mile at their southern end, they are bounded by faults; and they have been thrown into their present position partly by these dislocations, and partly in consequence of the anticlinal curve of which the ashes form the centre in the ground crossed by the section (Pl. 28, No. 3).†† In both these sections the Llandeilo beds overlie the porphyry on the west of Careg-Llyssog,‡‡ and abut on the same rock (repeated by the Tai-hirion fault), in the range of Y-Dduallt, where the felstones dip nearly due east about 45°.

Y-Dduallt itself consists of felstone, of a slaggy aspect, blue or grey in colour, often porphyritic, sometimes rudely columnar, and bearing a general resemblance to the equivalent rocks of Aran Mowddwy and Careg Aderyn. It is about 1,200 feet in thickness, and dips easterly at angles of from 40° to 50°. Beneath it, in the usual position, are the felspathic, calcareous, and conglomeratic ashes, dipping east about 45° beneath the trap. As we approach its base the angle decreases to 15° or 20°,§§ but these angles are much increased along the line of strike both north and south of this point.‖‖ In the area crossed by these sections the ash principally consists of a greenish grey felspathic base with felspar crystals, enclosing numerous irregularly rounded lumps of vesicular green and greenish grey trap, the vesicles being often filled

* Shown in the 6-inch sections, between Careg-Llyssog and Careg-Aderyn, in Sheet 19, Pl. 2, and between Careg-Llyssog and Penmaen, in Sheet 37, line 3.

† One mile and a half west of Llanuwchllyn.

‡ Dolhendre is a house lying 1½ mile W.N.W. of Llanuwchllyn.

§ Two miles from Llanuwchllyn, a little north of west.

‖ Moel-y-menyn lies 1¼ mile S.S.E. from the top of Arenig.

¶ Moel-llyfn-nant is a trigonometrical station 1¾ mile south-west of Arenig, Map 75 S.E.

** Two miles and three quarters almost directly south of Arenig.

†† *See also* Sheet 19, line 2, and Sheet 37, line 3.

‡‡ The sections cross near the point, one going north to the Menai Straits, [illegible] other west to Harlech Cardigan Bay.

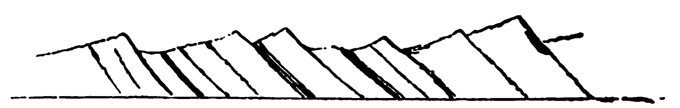
§§ Where crossed by the 6-inch section, Sheet 19, line 2.

‖‖ Six-inch section, Sheet 37, line 3.

with quartz and carbonate of lime. This general lithological character is frequent, not here alone, but in some of the ashes further south, and also on Cader Idris and Aran Mowddwy, reminding the observer of those viscous masses shot from volcanoes that fall among accumulating ashes during periods of eruption. Being generally green, and forming a large part of the ashes, these are in places almost indistinguishable from the more rubbly descriptions of greenstone, such as occur on parts of Cader Idris and south of Y-Dduallt on Craig-y-Benglog.

The lower part of the ash between Y-Dduallt and Rhobell-fawr has a compact blue base, with embedded slaty flakes. In places it resembles some of the felspathic rocks that have been poured out as streams of lava, so much so, that in a hand specimen, or even *en masse* on the ground, the inexperienced observer might readily be deceived. The instructed eye, however, soon detects its bedded character; and, when walking along the strike of the country, the upper surfaces of thick strata are seen dipping eastward in frequent succession, thus—

Fig. 9.



Sometimes distinct crystals of felspar are sparsely scattered in the blue base; and again, broken crystals of the same mineral are often thickly set in it, giving a beautifully porphyritic aspect both to the weathered surface and to the freshly fractured stone.

As usual, various interstratifications of slate occur in the ashes. One of these, about 600 feet above the base, passes from near the Dolgelli road several miles to the northward. It is from 100 to 200 feet thick.* Further south, it doubles that amount. Northward, it thins entirely away before reaching 'R-allt-llwyd. Another well-marked but short band separates the Y-Dduallt felstone from the ashes. Others are of frequent occurrence, so small, however, and inconstant, and so apt to pass in all directions, gradually or suddenly, into pure ashes by the admixture of what was once volcanic dust and loose crystals of felspar, that, on the map they are inseparable from the more purely volcanic matter. These lenticular interstratifications represent on a larger scale what takes place on a small one in the case of flaky lines and other thin and short interlaminations of slaty matter among the ashes, and afford ample cause of perplexity to him who attempts to map out every alternation of the strata with minute accuracy.

Intruded greenstones occur in the ashes. One, a quartz amygdaloid,† runs nearly in the line of strike; and the greater part of Craig-y-Benglog is also formed of greenstone intruded more irregularly and on a larger scale. This rock is green and also amygdaloidal, the vesicles being mostly filled with quartz, which is generally covered with a thin coating of very dark chlorite. It belongs to the same class as the vesicular greenstone that forms the summit of Cader Idris and part of the western side of Geu-graig.‡

Around this neighbourhood the felspar porphyry is about 1,200 feet, and the ashes 1,300 feet in thickness; a great diminution when compared with the thickest parts of the same masses on the Arans, and about equal to their development on Moel-ddu at the north end of the Aran range.§

Between the ashes and the greenstone of Rhobell-fawr there is a band of black shale, varying from a quarter to three-quarters of a mile in width.‖ Rising from under the lowest ashes, it belongs to a set of strata, the fossils of which, further north, clearly belong to a low zone of the Llandeilo flags. A

* Where crossed by the 6-inch sections (Sheets 29 and 37).
† Crossed by the section (Sheets 29 and 37).
‡ Map Sheet 59, Pl. 28, No. 1, and diagram fig. 6.
§ Fig. 8, and 6-inch sections, Sheet 37, lines 3 and 4.
‖ Map 75 S.E.

trilobite, *Trinucleus*, was found in this zone, near Blaen-lliw, by Professor Sedgwick and Mr. Salter in 1843, 2 miles south-west of Arenig; but in the neighbourhood now described no fossils have yet been found in the strata close below the ashes. The greater part of the mass further down belongs to the Lingula flags. On the north and north-east similar black shales *underlie* the greenstone of Rhobell-fawr, a fact proved by two outliers of the igneous rock that lie directly on the slate at Craig-y-Dinas and Moel-gron, and also by the general behaviour of the rock.*

The black shale in the brook near Cefn-yr-Eryr dips towards Rhobell-fawr. Further south, however, the shale seems to overlie it, and both ashes and shale south-west of the sixth milestone on the Dolgelli and Bala road are interrupted by the Dolgelli and Bala fault, and by a branch dislocation which passes north-west by Ystum-gwadnedd, bringing the ashes above Llanfachreth into juxtaposition with the greenstone by a downthrow of about a thousand feet. Following this dislocation the shale beneath the ashes is again let in at Cors-y-garnedd, between the greenstone on which it rests and the fault, and from this point to the river Wnion, near Dolgelli, the ashes are brought against the greenstone, except at one small spot in the grounds of Nannau, by a north and south fault that passes through Llanfachreth.

As the greenstones of Merionethshire are not truly interbedded but intrusive, it is not easy absolutely to demonstrate these dislocations, nevertheless when we consider the winding contour of the rocks elsewhere, the directness of the supposed faults which often run in straight lines, and the fact that at the south-east side of the greenstone the black slates are cut sharply off by one of them, there remains but little doubt of their actual existence. The largest fault strikes from the river Wnion northwards through Llanfachreth to Aber-Seirw-mawr on the river Mawddach near Craig-y-Dinas. South of Llanfachreth it is a downthrow on the east, but further north the shift is supposed to be on the opposite side, the western boundary of the Rhobell-fawr greenstone running unusually straight, in a manner that indicates a prolongation of the line of dislocation (fig. 10).

From the foregoing description it appears that a certain district between Llanfachreth and the river Wnion is bounded by four faults (*see* Map 75 S.E.). Moel-Offrwm† lies in it, and the whole area is of the age of the lower ashy deposits. East and south-east of Llanfachreth the rocks consist of thick-bedded undulating strata, often so sandy that they rather deserve the name of felspathic sandstones than of volcanic ashes. Some of them pass into pure sandy grits. On the low ground north of Moel-Offrwm there occurs a finely stratified slaty rock of an apple-green colour. The west flank of the hill consists of grits, a little slate, and felspathic ashes, the last largely predominating. A patch of slate occupies the top, and the whole undulates south-easterly, here and there penetrated by greenstones which have been more or less thrust in between the beds. In the Deer Park it is difficult to separate the greenstone and ashes, for they are both of the same dark green colour, and in the ashes the lines of stratification are so faint that it requires careful observation to detect them. The crystals of felspar in them are, however, more scattered than in the greenstone, and seem mechanically mixed with rather than crystallized in the matrix. Altogether these green ashes convey the impression that they may have been formed of volcanic dust, of similar composition to the substance that constitutes the greater part of the eruptive greenstone of Rhobell-fawr.

Rhobell-fawr.—The immense igneous mass of Rhobell-fawr seems to lie irregularly on the broken edges of the Lingula flags in the manner shown in the following diagram, fig. 10.‡

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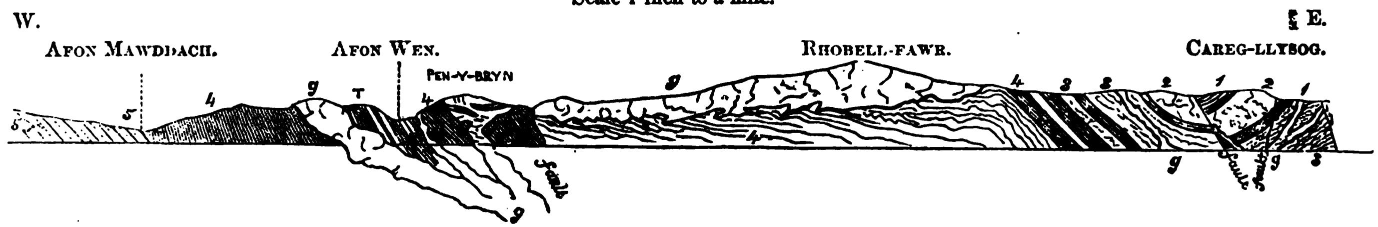
* *See* Fig. 10, and 6 in section, Sheet 37, line 3.

† Two miles N.N.E. of Dolgelli.

‡ *See also* the sheet of 6-inch horizontal sections, No. 37, line 3.

Fig. 10.—Section from the River Mawddach, near Dol-Melynllyn, across Rhobell-fawr to Careg-llysog.

Scale 1 inch to a mile.



No. 1 represents the Llandeilo, and perhaps a low part of the Bala beds in the faulted synclinal axis already described at pages 38 and 39; No. 2 the felspar porphyry; No. 3 the lower felspathic and calcareous ashes and conglomerates; No. 4, east of Rhobell-fawr the Tremadoc slate? and 4 under and west of Rhobell-fawr the Lingula flags, including the talcose, pyritous, and cupriferous schist marked T; No. 5 represents the Cambrian grits at Pont-ar-Gamlan, dipping under the Lingula flags at an angle of 50°. The greenstones No. *g* are drawn so as to show the kind of underground connexion that probably exists between the various masses exposed at the surface; and the rock of Rhobell-fawr is perhaps a part of the same great injection, lying partly on the surface of the broken and crumpled black slates described at p. 44.

The Lingula flags of this neighbourhood, near Tyddyn Gwladys, Moel-Hafod-Owen, and north by Craig-y-Dinas, have, in 1865, been carefully searched for fossils by Mr. Ezekiel Williamson, under the direction of Mr. John Plant, of Salford. The result has been the discovery of a great number of forms lying in well-marked zones. In a band of slate not far above the Cambrian grit the following shells were found:—*Obolella nana, Obolus apollinis* (? Dana), a small *Lingulella*, and *Theca corrugata;* of trilobites, *Agnostus pisiformis, A. princeps*, and another called by Mr. Plant *A. rex, Microdiscus punctatus*, and *Anopolenus Henrici*. In a higher bed, on the bank of the Mawddach, *Paradoxides Davidis* in great numbers. Higher still, on the western flank of Moel-Hafod-Owen, a *Polyzoon*, and of trilobites *Olenus Caractaci, O. micrurus, Agnostus*, and *Sao hirsuta*, said by Mr. Plant to be new to Britain. In higher beds, on the same hill, a new fucus *Buthotrephis Cambrensis, Gorgonites, Lingulella Davisii, Conocoryphe* (*Conocephalus*), and *Olenus*. In the upper part of the Lingula flags, towards Craig-y-Dinas, there were found *Orthis, Orthonota, Lingulella, Agnostus pisiformis*, and *Olenus;* and near the top, *Lingulella, Agnostus pisiformis, A. rex, A. princeps, Cheirurus, Dikelocephalus? Olenus scarabæoides, O. pecten, O. bisulcatus*, and *O. humilis*. The whole resembles the rocks of St. David's described by Mr. Salter and Mr. Hicks, and above these Mr. Plant considers that he has found Tremadoc slates.

As this is the largest mass of greenstone in Wales, and typical of some of the others, I shall describe it in some detail. In places it is well crystallized, but sometimes consists of amorphous matter of an apple green colour, enclosing large scattered crystals of dark green hornblende. The rock is generally very compact, and rings when struck with the hammer.

It occupies a broad tract of country, stretching from the banks of the higher part of the Mawddach, opposite Craig-y-Dinas, to Caerhedydd, 1½ mile south-east of Llanfachreth; from thence, at Ystum-gwadnedd, bending round northward by Moel Cors-y-garnedd to Moel-gron and Rhobell-y-big. Near Llanfachreth the boundary passes south under the west slope of Moel-Offrwm to the banks of the river Wnion, a mile and a half E.N.E. of Dolgelli, where it is cut off by a fault. Its opposite boundary begins a little west of Dolgelli, passes with much irregularity north by Llyn Cynwch to Pen-y-bryn and Cyplau, and from thence, with a curving outline, strikes eastward towards Moel-gron, along the slopes on the south bank of the Mawddach.

Its greatest length from north to south is about 7 miles, and its greatest width from east to west about 3 miles. Outliers of the same rock form the summits of Moel-gron and Craig-y-Dinas, so that before denudation it originally spread much further.

The surface of this mountain mass is barren and broken, and for long its vast succession of tumbled mounds conveyed to me the impression of successive ejections of lava having flowed from some concealed vent during the Lower Silurian period, and piled themselves on each other. But that the greenstone was not thus formed may be inferred from several circumstances:—First, along its eastern boundary, though the shales dip towards and under it near Moel-gron, yet the beds seem to rest upon it a few miles further south, and if the greenstone were a truly interbedded contemporaneous mass, it would, unless faulted, dip beneath and overlie shales all along the strike. Secondly, on the north boundary, while tracing its contour up Afon Geirw, though it is easy to discover that the slate in the channel of the stream underlies the greenstone, and is only exposed by denudation, yet here and there dykes pass from the main mass into and across the slate. Again, the excessive complication of the western boundary between Dolgelli and Pen-y-bryn bespeaks its intrusive character, for though some of the irregular forkings are due principally to contortion of the strata, yet others, as, for instance, at Llyn Cynwch, and between Llanfachreth and Pen-y-bryn, are the result of the injection of veins of greenstone from the mass, more or less in the lines of bedding, before these contortions took place. Intricate interlacings of slate also occur scattered over the mountain, generally so small that it is impossible to map them, but one marked example occurs on the summit, where the slates are so altered and mixed with small injected veins of greenstone, that it is almost impossible to separate them in mapping. Intense alteration of the shale or slate is, however, exceptional. On the east and north, and in great part on the west, they are black and carbonaceous, and therefore, because of their bad conducting quality, they are but little altered even close to the greenstone.

I have said that on its northern boundary the greenstone seems to rest on the black slate, and though generally much obscured, both by drift and peat moss, yet, wherever the water gullies show sections the slate is broken, crushed, and crumpled in a remarkable manner. This may possibly have been produced by the forcing of the greenstone in among the beds of slate which yet maintained a position approximately horizontal, while the rocks that once rested on the greenstone still remained undenuded, and before the later and more general disturbances took place that produced the greater contortions of the country; or the crumpling may have been caused during these later disturbances by a strong lateral pressure acting with effect on the soft slate, while the great unyielding mass of greenstone above prevented it from being broken by dislocations or from falling into larger and more regular curves.* It must be remembered that the greenstone once spread entirely across the valley of the Mawddach to Craig-y-Dinas, and perhaps far beyond, so that the rocks crossed by the section between Y-Dduallt and Craig-y-Dinas were also covered by the greenstone before it was removed by denudation, and this may account for their crushed appearance as indicated in the drawing. Along its western boundary the slates are generally of a lighter and more rusty hue, like ordinary Lingula flags. They contain many gritty beds, and on Moel-Hafod-Owen, where *Lingulellæ* are abundant, they are very much disturbed and altered, small bosses of greenstone being protruded here and there, which it is presumed are connected underground with the greater mass of Rhobell-fawr, and with the three detached patches that lie between Moel-Cynwch and the south-western slope of Moel-Hafod-Owen.† From the more felspathic greenstone of Hafod-y-fedw on the opposite bank of the Mawddach, a little more than a mile north of Llanelltyd, veins have been injected into the slate, which is hardened at the junction.‡ These are distinctly intrusive, for not only do they alter the rocks, but the most northerly patch branches straight across the strike of the slate forking out in various directions on the hills between the rivers Mawddach and Eden. Two branches of this injected mass are shown in the large horizontal section, sheet 29, line 2, immediately west of the Mawddach, and in the drawing it is unconnected with any greenstone intruding from below, its junction with the main body of the rock taking place about a quarter of a mile further south.

Talcose Rocks and Copper and Gold-bearing Beds of the River Mawddach.

Between Rhobell-fawr and the Mawddach there is a stream called Afon-Wen, not named in the map. On its western bank are certain highly talcose rocks, which lie between the river and the greenstone, and crossing the stream near Fridd-goch, pass southwards through the wood, across another unnamed brook a little below a picturesque bridge that lies about three quarters of a mile west of Llanfachreth. From thenee, gradually becoming less talcose, the beds strike towards Moel-Cynwch, and losing their peculiarities pass by degrees into the ordinary Lingula flags of the district. On the north they are cut off by an east and west fault, at what may be called the south-west angle of Moel-Hafod-Owen, above Buarth, where highly altered Lingula flags abut against them, dotted with spots of greenstone, which are perhaps connected with a closely underlying igneous mass.§ On

* Six-inch section, Sheet 37, line 3, and No. 29, line 2.

† Moel Cynwch lies 2 miles north of Dolgelli, and Moel-Hafod-Owen 2 miles W.S.W. of the summit of Rhobell-fawr.

‡ *See* section, Sheet 37, lines 2 and 3.

§ In the manner shown in the 6-inch horizontal section, Sheet 37, line 2, and in diagram fig. 10, p. 42.

the east the talcose beds are also partly faulted and partly overlaid by Lingula slate, against which the massive greenstone of Rhobell-fawr abuts.

The talcose rock itself is one of those problematical masses which it is impossible accurately to define, partly because of its variable character and partly from the difficulty of accounting for its origin. Where talc is most developed it necessarily possesses a flaky texture and a soapy feel; but these characteristics often rapidly change within an area of a few yards, and it either assumes an ordinary slaty structure, or, on the other hand, it passes into a hard felspathic-looking rock, which in some hand specimens it is almost impossible to distinguish from certain of the blue felspathic traps, and in others from the adjoining greenstone of Penrhos. Even there, however, from the presence of much talc, it is apt to have a flaky aspect, which generally becomes more apparent the more the rock is decomposed. It then, at the surface and in lodes, decomposes into a kind of talcose unctuous clay. Probably it may be a metamorphosed rock, perhaps originally ashy, especially since near Ffestiniog other beds, near it in structure, though higher in the series, pass in the line of strike into felspathic ashes. Iron pyrites and yellow sulphuret of copper are diffused in it, the pyrites occurring in numerous scattered crystals, and also accompanying minute copper-bearing veins, that are here and there disseminated throughout the hill. It was in a hollow in the hills formed by this talcose rock, about half a mile south and south-west of Moel-Hafod-Owen, that the well-known Turf Copper Mine was situated. The drainage of the ground occupied by the greenstone and talcose schist runs into it, and the water percolating through the rocks and rising in springs, carried copper in solution from those specks and strings that are more or less diffused through the mass of the hills above. In this manner the peat moss appears to have been partly saturated with copper in the state of a soluble carbonate. The turf was pared from the surface and burnt in kilns, and a large residue of valuable copper was afterwards separated from the ashes. Many thousand pounds' worth were thus extracted.

The hills have since been burrowed in all directions in search of the great lode or bunch from whence the copper was supposed by many sanguine adventurers to have been carried in solution to the peat. It has never yet been found, and probably does not exist, for the small quantities of sulphuret of copper diffused through the hill would be sufficient to account for its presence in the turf.

It is in the heart of the talcose schist of diagram No. 10 that the gold-bearing lode at Dol-y-frwynog occurs, cutting across the strike of the beds in a W.N.W. direction, in the low ground south of Moel-Hafod-Owen, on the east watershed. It is principally composed of white saccharoid quartz irregularly traversed by numerous small loose joints. Soft, unctuous, decomposing talc, and a little chlorite, pink carbonate of lime and manganese, together with much iron pyrites, are intermingled with it. In places the quartz assumes a semi-granulated aspect, and in general the substance of the lode is easily shivered. It was first opened in search of copper, and a shaft was sunk to a depth of about 20 fathoms, but during the process it proved to contain more attractive metal. In 1853, in the heaps at the mouth of the shaft, in several of the pieces, I saw gold in small flakes and grains irregularly disseminated through the quartz; and in a more select heap, on all the fragments it was distinctly visible; the surfaces of many of the masses being literally spangled with gold. Gold was also detected by Mr. Byers in the matrix of the copper-

bearing lode, about half a mile further south, and in the west Dol-y-frwynog lode, by the spot marked turf copper mines on the map.

"On the banks of Afon-wen, about a mile above the bridge, are some ruins of buildings, and below them, close to the river, the remains of charcoal ashes and bits of bones mostly covered with herbage. This place has a very singular name, which it has maintained from time immemorial, expressive of gold having been melted or worked there. This name, 'Merddyn coch 'r aur,' signifies 'the ruins of red gold.' The tradition is that the Romans formerly worked gold there. It may be well to observe, to those unacquainted with Welsh names, that no ancient place has a name but what is generally characteristic of its locality, or of some event that has taken place on or near the spot."*

In this neighbourhood, on the banks of the river Mawddach, gold, since 1843,† was worked in the branching quartz lode of Cwm Eisen. This lode also contains a little lead, and its principal branch composed of very hard quartz, runs north-easterly across the river about half a mile above Rhaiadr Mawddach. Of this mine Mr. Warington Smyth remarked in 1862,—"In 1846 "I had the opportunity of minutely examining some of the more "notable lodes near Dolgelli, in the district which had most "attracted attention. The Cwn Eisen mine, originally opened to "work some lead veins, had just been sold as a 'gold mine' for "14,000*l.*, neither buyer nor seller having made the slightest "approximation to an estimate of the length, breadth, or depth "of the auriferous ground, or of its fair average yield. The "assays and experiments made by Mr. Clement, who was called "in to act as metallurgist, showed that the specimens contained "a proportion of gold which would be considered highly profit- "able in the old gold mining districts of Salzburg, of Hungary, "and of America. Great expense was incurred by Mr. Bruin, "the new owner, not in working the ground, or in erecting appa- "paratus under the advice of men who were practised in gold "mining, but in following out the contrivances of ingenious "schemers; and the result was a very early suspension of all "operations."‡

I am informed by Mr. W. Smyth that on the N.W. side of the Mawddach, a little north of where it joins the river Gain, three parallel quartz veins have been discovered since I visited the country. They run east and west, and are crossed at nearly right angles by three others. The veins, which are small, lie near Gwyn-fynydd, below Moel-gwyn-Cynydd, and in 16 places specks of gold had been observed in them. It is also stated that gold has been detected in other places in the neighbourhood of

* Mr. Robert Byers, MS.

† Reports of the British Association, 1844, Mr. Arthur Dean. *See also* A. C. Ramsay, Proceedings of the Geological Society, 1854, vol. x. p. 242.

‡ The Mining and Smelting Magazine, vol. i., No. 6, June 1862.

Cwm Eisen, at Penmaen, and in the east and west lode at the south end of the greenstone near Gelli-gain, about 3 miles S.S.E. of Trawsfynnydd. I am, however, unable to say if the authorities, excepting Mr. Smyth, are to be depended on. Further south, on the hills above the estuary of the Mawddach, mining speculation has been rife for many years, chiefly in lodes that lie in the Lingula flags on the banks of the torrents that rise in the hills of Cambrian grit east of Llawllech. Originally the lodes of Vigra and Clogau, the property of the Crown, were chiefly worked for copper, with little or no profitable result, but about 1854 the discovery of gold in the rejected rubbish of the old workings at Clogau, and also in the abandoned lode, raised a kind of gold furor in North Wales, which many persons still remember to their loss. Of late years however, since 1859, the gold vein named "St. David's lode," which intersects the Lingula flags about a quarter of a mile further north than the old Clogau copper lode near the outcrop of the Cambrian grits, has been worked to great advantage. "The vein itself," says Mr. Smyth, "where well developed, is from 2½ to 9 feet in "width," and "is composed of quartz and calcareous spar, the "latter sometimes forming a body several feet in width; and "when the calcite puts on the appearance of a finely granular "and friable marble, it frequently contains gold; when, on the "contrary, it is large and coarsely foliated, it appears to be "entirely wanting in the precious metal." But the width of the lode is inconstant, sometimes degenerating into "a mere thread "of spar." In all, perhaps, about 40,000*l.* worth of gold has been extracted from this mine at small expense.

Gold has also been found in a lode in the Cambrian rocks a little further north, and at Cae-Gwernog, Perth-lwyd, the Prince of Wales mine at Gallt-yr-hafod, West Vigra, and from other mines gold has been extracted. The last named has been worked continuously since 1855. Gold has also been got, to the extent of two or three ounces per week, about three miles west of the south end of Bala lake, a faulted area of Llandeilo beds close to the felspathic porphyry near Castell-carn-dochan.

CHAPTER VIII.

The Arenigs, Llyn Conwy, and the Rocks in their Vicinity.—Fossils.

General Description.—The rocks of the Arenig mountains, and the district of Migneint and Llyn Conwy, lie on the same stratigraphical horizon with those of the Arans, and exhibit the same class of phenomena, for the component rocks are repetitions by the Bala fault of the same masses, some of them developed on a greater and others on a smaller scale. The felstone porphyry, over which flows the river Lliw,* has already been partly described,† and in doing so I have mentioned the ashes that *overlie* it, and *underlie* the black slates believed to be Llandeilo beds. Traces of these *upper* ashes are, indeed, occasionally found overlying the great masses of porphyry that form the crests of the Arans and Cader Idris. But where the igneous series is repeated by the great Bala fault, these *upper* ashes thin away west of the Bala road, about 3 miles south-west of Llanuwchllyn. Gradually becoming more developed as they pass north towards Arenig, they attain eventually a thickness of about 700 feet, and dipping east form the entire eastern flank and summit of the mountain (fig. 11).‡ The *lower* ashes that rise from underneath the felstones of the western range§ strike by 'r-Allt-llwyd northwards to Moel-llyfn-nant, and while the ashes above the felstone by degrees thicken, the lower series gradually decline in their northward passage to Moel-llyfn-nant, where they completely thin away. The felspathic trap, however, still continues; for the same rock that forms the summit of Moel-llyfn-nant crops out half-way up the western flank of Arenig (fig. 11), directly overlying the lower Llandeilo slate.

North of Arenig (maps 74 N.W. and 75 N.E.) the *upper* ashes cover a broad area, spreading eastward in the great anticlinal curve of the strata north of Bala, and thence striking west and north by Llyn Conwy to the river Machno. Through all this area, excepting on faulted ground, the ashes are directly overlaid by black Llandeilo shales and slates, and underlaid, as the fossils of Tai-hirion testify, by the lowest Llandeilo beds.

The Arenigs, Llyn Conwy, &c.—By referring to the maps it will be seen that the great Felstone lava beds, already so often mentioned, are continuous from the south, where they are both underlaid and overlaid by ashes; but it will be observed that in the short space between Moel-llyfn-nant and Arenig the lower ashes have entirely thinned out, for the felstone of Arenig rests directly on Lower Llandeilo beds. Beyond this point for several miles the lower ashes only appear beneath the same porphyry in a few streaks near Cerig-y-Bala and Tai-hirion in the district of Migneint.‖ The following diagram, fig. 11, will explain these particulars:—

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* Misspelt Llin in Map 74 S.W.

† Pages 38 and 39.

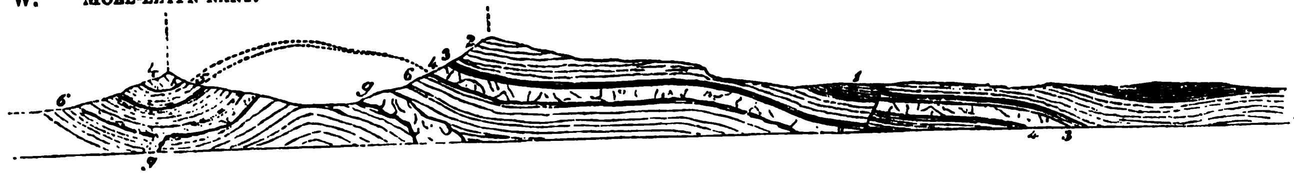
‡ Six-inch section, Sheet, No. 39 line 1.

§ Between Y-dduallt and Moel-llyfn-nant.

‖ Cerig-y-Bala is about 6 miles east of Ffestiniog, and Tai-hirion about 1 mile S.W. of Arenig-bach.

Fig. 11.

SECTION ACROSS MOEL-LLYFN-NANT AND ARENIG TOWARDS BALA.



No. 1 represents the black slaty shales of the Llandeilo beds, which occupy part of the low drift covered ground between Bala and Arenig. No. 2 shows the position of the upper ashes. A thin band of slate, No. 3, here separates it from the felstone, No. 4, which, at the base of Arenig, rests directly on the Lower Llandeilo beds, No. 6. An anticlinal axis in the hollow throws the same strata over to Moel-llyfn-nant, where the lower ashes come between the Llandeilo flags and the felspar porphyry, No. 4. *g* represents injected greenstones, also irregularly repeated in the anticlinal and synclinal curves.

Where this section crosses, the porphyry is only about 300 feet thick, but on the north side of Arenig, on the crags of Maen-grygog and Daear-fawr, and on the opposite bank of the river between Y-foel and Bryn-maen-llifo,* it greatly increases in bulk. It consists of dark grey porphyry, with small distinct crystals of yellow felspar in a felspathic base, but further north it gradually becomes less porphyritic. In some places it is columnar, and in others largely jointed. It disappears close by Llyn Serw, between Arenig-bach and Ffestiniog.

The greater part of Arenig and about 15 square miles on the north (including Mynydd Nodol, Arenig-bach, Craig-ddu, and Llechwedd-llyfn) consists of wide spreading undulations of the upper felspathic ashes, overlaid by black Llandeilo slaty shale. The large maps and sections† show that this area, owing to undulations of the strata, is partly covered by about 800 feet of ashes. Fig. 11 refers to part of this area. Here and there it is faulted. One of these faults, about half a mile east of Llyn Arenig, strikes northerly, and throws in the Upper Llandeilo beds on the west for somewhat more than a mile.‡ It is met by an east and west fault on Cefn-llwyn-y-bugail, which throws the Llandeilo beds against the trap on the south. Two other downthrows on the north-east affect the strata on a broken anticlinal line between Gylchedd and Moel Phillip. Others occur south of Y-Garn throwing in the Llandeilo beds in a broken synclinal between hills of volcanic ash. At Waun-Carnedd-filiast the ashes form a sharp angle caused by the meeting of north and north-west faults that each affect the Llandeilo beds, one being a downthrow on the west, the other on the north-east.§ The shift of the beds in the largest of the two probably does not exceed 500 feet.||

The ashes of Arenig are difficult to describe with precision. In some places (as, for instance, near the top) they are decomposed and shivery, and in others rough and almost scoriaceous looking. On the bare steeps that surround Llyn Arenig they are thick-bedded, and frequently porphyritic, but so massive, and they so much resemble some of the true felstone porphyries that the observer is apt to doubt of their truly stratified character, especially as it frequently happens that they are so much jointed that in places they look almost columnar. Still, when viewed in favouring lights on a large scale, the long lines of massive beds that streak the steep flanks of the hills generally become sufficiently apparent, and when traced along the strike to Mynydd Nodol and Arenig-bach all doubt ceases, for, by degrees becoming less jointed and massive, their true bedded structure comes out with perfect distinctness. Nevertheless it must be confessed that on Arenig, and for some distance further south, the subject is beset with difficulties.

"In some places," says my colleague Mr. Aveline,¶ "it is quite impossible "to draw any definite line between the porphyry and ashes. They seem to pass "imperceptibly into each other, and the fact that some even of the massive "felstones have a bedded appearance makes the separation still more difficult. "When much decomposed there is no apparent difference between them. "When you go over the ground between Llyn Conwy and Arenig-bach, and "see these bedded rocks rolling and undulating across the country, you can- "not hesitate as to what they are; and again, if you examine the massive "rocks south of the Arenigs, often undoubtedly columnar, you would at "once decide that they are good trap rocks. But if one person were "to trace the ashes from the north, and another the traps from the south, "each would carry his lines well into the territories of the other. Possibly "these difficulties may be accounted for as follows. On the Arenig area the "ashes and the trap were not formed as distinct masses by different eruptions, "but they may have accumulated at the same time, the trap not extending "much to the north, where the accumulation of ashes was greatest, and on

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* Under Arenig-bach.

† Maps 74 N.W. and S.W., and 6-inch sections, Sheets 29 and 31, and lines 1 and 5.

‡ Diagram, fig. 11, and 6-inch section 39, line 1.

§ Gylchedd lies 2¾ miles S.S.E. and Waun-Carnedd-filiast 3 miles south-east of Yspytty Evan. Moel Phillip and Y-Garn about 4½ miles north-west of Bala.

|| Maps 74 N.W. and S.W., and Section, Sheet 31, line 5.

¶ MS.

" the south, where in a less degree the ashes also fell, they may have got mixed " with and been partly melted by the hot lava-flows, and in other cases been " hardened and altered, but not so completely as to have lost their bedded " appearance. These remarks only refer to the upper ashes, and in some " respects do not apply to the trap under Arenig, which appears somewhat " different from the rocks further south, and I am not sure that it is not " partly intrusive." The probability of this is not diminished by the presence of certain small bosses of porphyry on the west in the district of Migneint, and near Llyn Treweryn.* These are probably intrusive, and may possibly represent some of the volcanic necks through which the lava rose towards the surface.

Throughout a large part of this region the lines of stratification form a striking feature in the landscape, giving a distinct character to the hills of Mynydd Nodol, the broken ridge by Afon-Hescyn, Llechwydd-llyfn, and Arenig-bach. On Arenig-bach itself they lie in long terrace-like lines along the western and northern crags, and from its summit an experienced eye can follow the flowing undulations of the strata on the flanks of the eastern hills. Some of the rocks are thick, massive, and porphyritic; others are thinly banded, and in places almost slaty-looking. Occasionally the beds weather slaggy and harsh, but even then retain their well-stratified character. Between Arenig-bach and the river Machno† the same porphyritic brecciated and bedded ashes occupy a large part of Migneint and the hills round Llyn Conwy, and through all this district they are sparingly intermingled with short lenticular slaty bands.

The Tai-hirion fault, which is of considerable magnitude, passes southward across Migneint, throwing Bala and Llandeilo beds, ashes, and trap down on the west.

The rocks between Arenig-bach and Afon-Conwy are obscured by peat-moss and drift, but enough here and there crop to the surface to render the boundary tolerably approximate. From the Conwy to the Machno it is sufficiently distinct. On Bryn-rhuddod ‡ the strata lie nearly flat, but in general the ashy beds undulate to the east on the summits of the hills. A good section is exposed on the north shore of Llyn Conwy. The strata dip easterly from 8° to 12°. Between Llyn Conwy and the Machno they undulate northward and eastward, and finally dip towards the Machno fault, coating the hill that slopes to the river, and crowning the cliffy bank that overhangs the high road between Hafod-yr-edwedd and Caregog, in the manner shown in the following diagram:—

Fig. 12.

SECTION FROM 'RALLT-DDU, NORTH OF LLYN CONWY, ACROSS THE RIVER MACHNO.

1. Lower Llandeilo beds.
2. Felspathic and porphyritic ash.
3. Bala beds. *f* fault.

As a whole the ashes of Migneint and the country near Llyn Conwy dip eastward under the black slate of the Upper Llandeilo beds at angles between 20° to 30°. These slates are the equivalents of those that rest on the igneous rocks of Arenig and Aran Mowddwy.

* Llyn Treweryn lies 6 miles E.S.E. of Ffestiniog.
† Two miles south-west of Penmachno (Map 75 N.E.)
‡ One mile south of Llyn Conwy.

The country of the Arenigs and Llyn Conwy is especially interesting, owing to the occurrence of fossils in the slates that lie close above the igneous rocks, and also in beds that lie conformably close below them. The comparison of these fossils, separated by a vast thickness of interbedded lavas and volcanic ashes, is important, since it partly enables us to judge if their ejection was accompanied by physical disturbances on a scale and of a kind sufficient to influence the marine life of the period. The details of this part of the subject are given at page 74.

CHAPTER IX.

THE IGNEOUS AND ASSOCIATED ROCKS BETWEEN LLYN CONWY AND MANOD-MAWR, NORTH OF FFESTINIOG.

General Description.—We have now reached an area so shattered by faults that it is impossible, without names for each stratum, to convey by writing any clear idea of the relations of all its parts, although on the ground, after much labour, it is practicable to understand these relations with precision. Bounding the Cambrian rocks on the east, there is a large fault, already mentioned, which, passing near Trawsfynydd and Ffestiniog, cuts across the felspathic rocks north of the Ffestiniog syenite, and is lost in the slaty beds beyond (Maps 75 S.E. and N.E.). It is east of the northern part of this dislocation that the shattered country lies, and the reason of so many cracks and shiftings occurring in so small an area is probably the bend in the strike produced by those forces that contorted the rocks of the country. They lie, so to speak, in a corner, and the wrenched and crushed strata have been so much fractured that, as in the case of the Bala beds, north-east of Bala, fragments of the country occur here and there dropped in between enclosing faults in the most unexpected situations.

All the rocks of this complicated area belong to the horizon of the igneous rocks and slates already described.

About 5 miles east of Ffestiniog, where the road branches to Penmachno and Yspytty Evan, a fault strikes northerly, following the course of the valley of Caregog, where it is cut off by the Penmachno fault. It is also a lode, and may be distinctly traced in a series of old workings from Ffynnon Eiddew to Caregog. In several places it is of very great width and solidity, being composed of a kind of cherty felspathic substance mingled with quartz not unlike some of the rocks of Paris mountain in Anglesey. The country is thrown down on the west by this fault, and repeated on a large scale, and on its opposite sides the different kinds of strata are readily distinguishable, those on the east being light

grey, hard, and banded with grits, like the greater part of the true Lingula flags of Ffestiniog and Dolgelli, while those on the west are dark blue and exclusively slaty, as is usual with the lower portion of the Bala and the Llandeilo beds, to the latter of which they probably chiefly belong. Here and there small openings have been made, with the view of quarrying for slate.

Large masses of solid felstone and ashes form the ridges of Y-Garnedd and Y-Gamallt,* and rising from beneath the Llandeilo beds on the west side of the Ffynnon Eiddew fault, it is evident that they bear the same relation to these rocks that the igneous masses of Arenig and Llyn Conwy do to the equivalent strata elsewhere. The same is the case with the igneous rocks of the Manods and of the two Moelwyns near Ffestiniog. The whole of the igneous series between Llyn Conwy and the Manods has in fact been repeated again and again by faults. South of these hills, towards Llanfrothen, are Tremadoc slates, with the Lingula flags below them.

Y-Gamallt, &c.—A north-east fault passes from Llyn-y-Morwynion towards Cerig-y-lladron, and being a downthrow on the north-west, the Llandeilo beds are thrown against Lingula slates for about a quarter of a mile, near where the turnpike road crosses Nant-pystyll-gwyn.†

A little south of this dislocation (which may be termed the Cerig-y-lladron fault) three others occur. One of them is probably a continuation of the Ffynnon Eiddew lode, and another of the lead lode of Cerig-y-lladron, and among them they let in two patches of solid feltspathic ashes, that form the broken rocks of Bryniau-fonlle and Cerig-yr-iwrch.‡ The latter is overlaid by a triangular space of Llandeilo beds; the former is profusely intermingled with irregular interstratifications of slate. They represent alike the ashy beds of Llyn Conwy and Meignint and the lower part of the rocks of Y-Gamallt.

The rocks that constitute the higher part of the ridge of Y-Garnedd and Y-Gamallt, though somewhat faulted, are continued by Llyn-y-gors and Llyn-y-ffrith-graig§ to Tan-y-rhiw, where they are cut off by the Machno fault. They consist in great part of massive blue felspathic porphyries, which, especially on Y-Gamallt, have all the appearance of rocks that have been melted. Nevertheless, in this particular area there are the same difficulties to contend with that beset the geologist in his endeavours to disentangle the various species of igneous rocks on Arenig. From various points of view it presents a largely bedded aspect, although it is perhaps likely that the seeming beds are joints and planes, similar to those that occasionally puzzle the geologist on parts of Cader Idris, or on Careg Aderyn, where the rock is true felspathic lava. Cases indeed occur, although rarely, when even those who have devoted years to the study of such rocks find themselves at a loss to determine the distinction between true felspathic lavas and felspathic dust, to which pressure, and that kind of consolidation in part consequent on internal decomposition and re-formation of new silicates, have imparted a hardness, solidity, and homogeneous character equal to that of the melted porphyry itself.

Round Llyniau-y-Gamallt, and northwards from these lakes to the Machno fault, beds of undoubted ashes underlie these doubtful rocks. They are sometimes porphyritic, often largely conglomeratic or brecciated, and frequently interstratified with lenticular layers and beds of slate. A striking example of volcanic conglomerate occurs near the south end of the larger lake of Y-Gamallt. Both ashes and overlying porphyry are cut off on the north-west in

* Three miles and a half north-east from Ffestiniog.

† Three miles E.N.E. of Ffestiniog.

‡ Three and a half miles from Ffestiniog, a little north of east.

§ One mile and a half from Llyn Conwy, a little south of west.

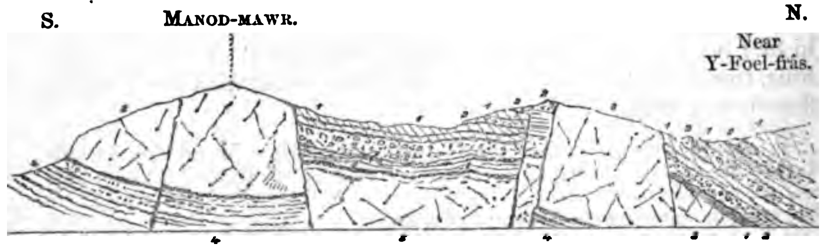
the valley by the Machno fault, which throws a low part of the Llandeilo slates against them in a similar manner to what takes place in the prolongation of the same dislocation a mile lower down the river at Caregog.

On the east side of Manod-mawr* there is a long fault that passes north through Cwm Penamnen and Dolwyddelan to Llyn Geirionydd, about 2 miles west of Llanrwst.† It is a downthrow on the east. The structure of the country on its west side is comparatively simple. I shall first describe it, and then apply the knowledge thus gained to the explanation of part of the more broken ground on the east.

Manod-mawr, Manod-bach, Llyn Conwy, &c.—A north and south section from the neighbourhood of Y-Foel-frâs, across Manod-mawr, exhibits, in descending order, the following arrangement:—

Fig. 13.

SECTION FROM Y-FOEL-FRÂS, ACROSS MANOD-MAWR.



1. Slates of the Llandeilo beds.
2. Felspathic ashes and conglomerate.
3. Felspathic porphyry.
4. Lower Llandeilo beds, &c.

Near Y-Foel-frâs the dark slates, No. 1, dip north, and these are succeeded by several ashy beds, No. 2, which are interstratified with other beds of dark blue slate, also marked No. 1. The pools of Llyn-y-Drumboeth and Llyn-bywydd lie in hollows occupied by this slate, which is the equivalent of that in the quarries a little further west. The ashes underneath this band are very conglomeratic, felspathic and slaty fragments being agglomerated in a mixed slaty and ashy matrix. They are remarkably inconstant, slates and ashy beds wedging out, disappearing, and again thickening, in a manner that shows great irregularity in their original accumulation. Passing westward these ashes gradually diminish in thickness, and the uppermost bed thins almost entirely away in the slate quarries, about half a mile west of Llyn-y-Drumboeth. It is exceedingly talcose, and contains numerous crystals of iron pyrites, and in these respects strongly resembles the talc schist of Dol-y-frwynog, already described. In proportion as the ashy beds thin out the beds of workable slate thicken and improve in their westward strike. A little south of Llyn-bywydd, a north-east and an east and west fault throws a part of these beds against a mass of felspathic porphyry (No. 3). These ashes and slates, before the denudation of the country, once spread across the Manods, from which position they have been dovetailed into the midst of the felspathic porphyry, by two principal east and west faults that cross Manod-mawr, and gradually approach each other till they coalesce and abut on a north and south dislocation that skirts Manod-bach on the west. This clearly accounts for the presence of that thin coating of slate and ashy bands in Fig. 13 that lies in the elevated hollow north of Manod-mawr. These rest on thick beds of volcanic conglomerate and porphyritic ashes (No. 2), that crop from under this slate on its western edge, and barely casing the surface, undulate down the inclined rocky slopes to Tal-y-Manod in a triangular space bounded by the faults above described. The slaty beds on Manod-mawr are of no great thick-

* Manod-mawr lies 2 miles N.N.E. of Ffestiniog.
† Maps 75 N.E. and 78 S.E.

ness, and at all points underneath them the conglomerate may certainly be found, but to determine its actual depth would require the construction of a section on a true vertical and longitudinal scale. The conglomerate is the equivalent of that which strikes south-west from the outflow of Llyn-bywydd. In both localities a band of slate underlies it, patches of which, too small to map, are here and there exposed by denudation amid the rocky mounds between the faults immediately north of the Manods. The felspathic porphyry (No. 3) lies beneath, and where affected by faults the ashes and slates are thrown against it in the manner shown in the diagram.

The porphyry of the Manods is massive, and consists of small crystals of felspar set in a blue felspathic base, which in places becomes so dark and hornblendic-looking that the rock might almost be termed a greenstone. It is probably about 1,500 feet thick. The slaty band below in immediate contact with it has been altered by heat, but that above is altogether unchanged, proving the porphyry to be part of an old lava flow. Beneath the slate on which it rests are beds of grey sandstone and slaty flags (No. 4). In these Mr. Salter found Calymene, Asaphus and other Lower Llandeilo fossils.

Position and fossils both indicate that these beds are the equivalents of the slates of Tai-hirion, and the grits of Carnedd Iago, and like them they also prove that the igneous rocks of the Manods and Moelwyns were ejected, not at the close of the deposition of the Lingula flags, but later, namely during the deposition of the Llandeilo beds.

The Dolwyddelan and Manod-mawr fault cuts off the Manod rocks, so that the equivalents of the Llandeilo beds and ashes of Llyn-bywydd and Manod-mawr are thrown down on the east. This accounts for their position so far south, for of course they once covered the whole of the lower rocks near, till removed by denudation. The slate quarries in the beds interstratified with ashes that are enclosed between the minor north and south faults that include Bwlch Careg-y-frain are therefore the equivalents of the southern part of the slate quarries west of Llyn-du-bach. They dip north-west at a low angle. Two faults branch off from that of Manod-mawr in Cwm-tegwel, and another zig-zag crack unites them north of Hafod-Yspytty. The latter is a downthrow on the north, and the porphyry that is here enclosed in the triangular space between three faults, is equivalent to that of the Manods. The dislocation that skirts the south-east base of Manad-mawr is probably a downthrow on the north-west. Two miles E.N.E. from Ffestiniog, the Roman road crosses the brook at a ford called Rhyd-yr-Helen. From this point a fault strikes N.N.E., and joins that of the Machno near Rhiw-bach. The rocks are thrown down on the east, and the concentrically arranged beds of slate and ashes about half way between Manod-mawr and Llyniau-y-Gamallt are the probable equivalents of similar interstratifications about a mile further north. Another fault passes from near Moel-machyrig and west of the Gamallt lakes to Craig-y-gareg-lwyd above Llyn-y-Morwynion,* where it branches into many dislocations too numerous to define on the map. This may be termed the Gamallt fault. Between these two main faults west of Llyniau-y-Gamallt the rocks roll over in an anticlinal curve faulted on its east side, and the ashy and slaty layers of Llyniau-y-Gamallt are the equivalents (changed in lithological composition) of the lower part of the workable slates north of Manod-bach. Several easterly dislocations pass between the Rhyd-yr-Helen and Llyn-y-ffrith-graig faults. The principal of these passes E.N.E. from Rhyd-yr-Helen in the direction of the Gamallt fault, which it joins a little south of the stream that rises in the lakes. It is a downthrow on the south, and all the ashes, slates, and felspathic porphyries that lie between it and Careg-lwyd are the equivalents again repeated of similar interstratifications lately described. Some of the slates have been quarried. They dip east and north-east. It is even possible that one or more of the porphyries of the area represent on a smaller scale the greater porphyritic masses of the Manods and of the block of country above Hafod-Yspytty. The rocks of Y-Garnedd and Careg-y-foel-gron belong to the same set. Other more marked dislocations occur in the immediate neighbourhood. On the summit of Y-Garnedd the word *smashed* is the only term that expresses the state of the country, veins and

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* Three miles south-west of Penmachno.

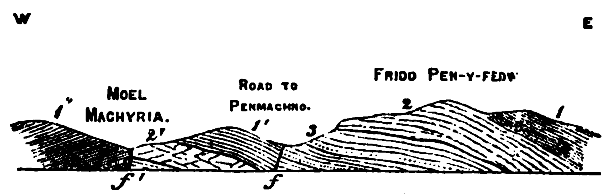
branches of quartz confusedly intermingled with slaty matter ramifying in all directions over a broad space for nearly a quarter of a mile.

The general effect of the entangled maze of faults north and north-east of Ffestiniog is that the Llyn-bywydd slate rocks * and their equivalents at the slate quarries near Llyn-y-drumboeth are thrown down so as to form the hills that overlook Llyn-y-Morwynion about 2½ miles to the south. The ashy and slaty beds, which are associated with the slates near Llyn-y-drumboeth and Llyn-bywydd are by these faults repeated, first, on the Manods, next in and around the quarries immediately north of Bwlch-Careg-y-fran, and again further south on the east side of Sarn Helen; and not only are the slaty beds that are interstratified with the ashes smaller in quantity and otherwise deteriorated, but near Rhyd-yr-Helen various minor beds of more solid porphyries are associated with them, in part equivalent to the great porphyritic masses of the Manods. The following diagrams will help to explain the structure of this difficult country between the Manods and the Llyn Conwy and Meignint ashes, —an area so perplexed and intricate that it is almost impossible for any one to comprehend its details who has not, like Mr. Aveline and myself, mapped each one of its component beds.

Immediately north of Llyn Conwy, an east and west line between Fridd Pen-y-fedw and the slate quarries near Tan-y-rhiw,† gives the following section:—

Fig. 14.

East and West Section North of Llyn Conwy.



1, 1′, and 1″. Llandeilo flags.
2 and 2′. Felspathic ashes.
3. Llandeilo beds, &c.
f. Fault.

No. 1 represents the dark blue slate of the Llandeilo beds that rests on the igneous rocks all round the great Merioneth anticlinal, 1′ the repetition of the same rock by the Ffynnon Eiddew fault, and 1″ the equivalent Llandeilo beds near Tan-y-rhiw on the north-west side of the Penmachno fault *f*. No. 2 represents the felspathic ashes of Llyn Conwy, and 2′ a low-lying part of the equivalent rock of the Gamallt range. No. 3 indicates the Llandeilo slate and grit underneath the ashy beds, the higher part being equivalent to the fossiliferous bands of Tai-hirion and Carnedd Iago, and the lower strata perhaps representing part of Lingula flags which further south, on the banks of Llyn-y-dywarchen, contain Lingulæ. The whole *country* is thus repeated by the Ffynnon Eiddew and Caregog fault marked *f*.

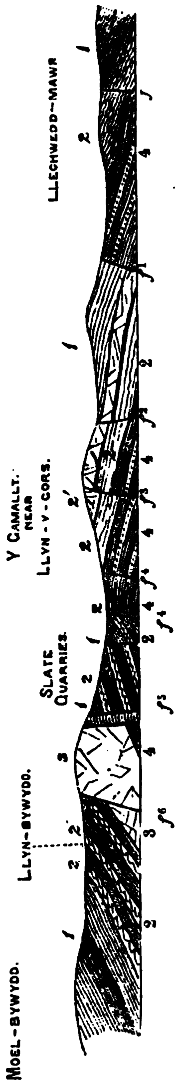
The same rocks show the following more complicated arrangement on a north-west line from the slate at Llechwedd-mawr, half a mile east of Cerrig-y-lladron‡ to Moel-bywydd north of the Manods.

* A mile and half north of Manod-mawr.
† About 5 miles north-east of Ffestiniog.
‡ About 6 miles from Ffestiniog, a little north of east.

Fig. 15.

SECTION FROM LLECHWEDD-MAWR, SOUTH OF LLYN CONWY, TO MOEL-BYWYDD, NORTH OF MANOD-BACH.

N.W. S.E.



No. 1 represents the Llandeilo beds near Cerrig-y-lladron (a little south of the river Conwy), and the same slates near Y-Gamallt, and at Moel-bywydd.

No. 2. The ashes of Llyn-Conwy and their equivalents north of Llyniau-y-Gamallt, near Bwlch-Careg-y-frain, and by Llyn-bywydd, near the slate quarries. No. 2′ is part of this series, and represents the felspathic porphyry of Y-Gamallt.

No. 3. Part of the Manod porphyry, about a mile north of the trigonometrical station on Manod-mawr.

No. 4. The base of the Llandeilo beds, and underlying strata.

The letter *f* shows the position of a small fault that slightly affects the junction of the Llandeilo beds and ashes near Cerrig-y-lladron, and f^1 the effect of the Ffynnon Eiddew fault, repeating the Llandeilo beds and the underlying igneous rocks. f^2, a small downthrow on the south-east near Llyn-y-gors; f^3, another on the north-west; f^4, three faults, throwing in small sections of the Llandeilo beds and thin bands of ash, &c.; f^5, the faults immediately east of Manod-mawr, throwing down the ashes and slates of the Llandeilo beds on the east; and f^6, an east and west fault near Llyn-y-bywyd, throwing down on the north interstratifications of ashes and slate (Llandeilo beds) against the Manod porphyry.

The whole country illustrated by this diagram lies in the form of a faulted anticlinal curve, the ashes of Llyn-bywydd, Llyniau-y-Gamallt, and Cerrig-y-lladron being identical, although there are considerable vraiations in the nature of some of their associated beds. Thus the ashes of Y-Gamallt, like those of Llyn-y-drumboeth, are interstratified with slates; but, while there are great and profitable slate quarries near the latter place, near Y-Gamallt, the equivalent slaty bands in the ashes are short, irregular, and none of them of workable quality. The ashy bands have thickened, and the slaty beds thinned to comparative insignificance. The rocks of Llyn-Conwy and Cerrig-y-lladron exhibit a still larger development of the same igneous material, forming a thick solidly bedded mass of felspathic porphyritic and brecciated ashes, sparingly

intermingled with short lenticular bands of slate. The felspathic lava beds have also their rapid variations, and though some of the bands near Llyn-y-Morwynion may represent the Manod porphyry, there is no trace of porphyritic lava at Llyn Conwy and Cerrig-y-lladron. The trap that overlies the ashes on the Gamallt range is absent above the ashes of Llyn Conwy and Llyn-bywydd, at the opposite ends of the anticlinal curve.

The great mass of the Manod porphyry might be supposed to be an intrusive boss, especially as (eliminating the faults) it thins away so rapidly both to the east and west. Nevertheless, it decidedly underlies unaltered slates and ashes, and overlies altered Llandeilo beds, and altogether it maintains so regular a horizon, and otherwise so behaves in connexion with the faults, that all the evidence is in favour of its non-intrusive and interbedded character. This probability is not diminished by the circumstance that between Cerig-y-lladron and the Arenigs there is a mass of porphyry similar in lithological character to that of the Manods, and occupying the same position between the ashes and the underlying fossiliferous strata.

Its disappearance between Llyn Serw and the Manods is no proof that the masses are not equivalent and contemporaneous, for the original edge of the lava current might be so irregular, that we must not expect to find it cropping out everywhere from beneath the overlying ashes, which, as originally deposited, may in places have overlapped its edges. If this be so, then it may spread northward from Llyn Serw deep under ground, in such a way, that before the faulting and denudation of the country it was continuously connected with the porphyry of the Manods.

Many of the faults in the area above described, between the Llyn Conwy ash and the Manods, are also lodes; and one of these, at Llechwedd-mawr, was worked for lead. The fault that runs north from Ffynnon Eiddew is a broad lode, chiefly filled with quartz and a kind of hard cherty matter. In places it has been worked for manganese. On a broad space on the top of Y-Garnedd the rocks have been much dislocated, and the dislocations are entirely filled with quartz. The south-west lode at Rhyd-yr-Helen yields a little copper pyrites. The north and south lode west of Llyniau-y-Gamallt was formerly worked for lead, and several others round the Manods yield small quantities of that mineral mixed with quartz with which the lodes are chiefly filled. It is said also that traces of gold have been found in lodes north of these mountains, but none of the lodes of any kind have been worked profitably for many years.

CHAPTER X.

The Lingula Flags and Tremadoc Slates between Rhobell-fawr and Traeth-bach.—Fossils of the Tremadoc, Llandeilo, and Bala Beds in Merionethshire.

General Description.—North of the great mass of greenstone that forms Rhobell-fawr the Mawddach flows from east to west. Between this river and Traeth-bach* the Lingula flags preserve the same character that they possess on the shores of the estuary between Barmouth and Dolgelli, and the fossils are the same, *Lingulella Davisii*, *Hymenocaris vermicauda*, *Paradoxides Davidis* and *P. Forchammeri*, *Olenus micrurus*, *Agnostus princeps*, and *Cruziana*, with many other undescribed forms. (Plates 2, 3, and 4.)

The Tremadoc slates near Tremadoc and Llandeilo beds are not yet known on the flanks of Cader Idris and the Arans, but this may arise from the circumstance that they have been more

* Map 75 N.E. and S.E.

closely hunted for fossils. On the northern curve of the great Merionethshire anticlinal the same assemblage of forms was found by Mr. Salter along a range of 20 miles between Taihirion and the estuary of Traeth-mawr.

The whole series down to the Cambrian grits is pierced by numerous dykes and masses of greenstone, but no contemporaneously interbedded porphyries are associated with Lingula flags here or elsewhere in North Wales.

Lingula Flags.—North of Rhobell-fawr the Lingula flags, with various undulations, dip more steadily eastward than in the slaty ground that partly surrounds the mass of greenstone. They chiefly consist of grey micaceous slate, sandy flags, and grits, here and there interstratified with dark blue or black slates. Good examples of the more sandy beds, sometimes ripple-marked, may be seen on the banks of the Mawddach and on the hills north and north-west of Craig-y-Dinas. The boundary between the Cambrian and Silurian rocks runs by the beautiful waterfall of Pistyll-Cain, where, however, the rocks are so much fractured and confusedly intermingled with greenstones, that is impossible to say whether or not the very lowest beds join the Cambrian grits. They are, however, very low in the series, seeing that a little further north the grits of Craig-y-Penmaen dip steadily and regularly under the Lingula flags at angles of about 30°. In this neighbourhood one trilobite, *Paradoxides Forchammeri*, was found by Mr. Selwyn near the gold mine in Cwm Eisen, and numerous specimens of *Lingulella Davisii* (Pl. 2) in the banded grits and slaty flags west and north-west of Craig-y-Dinas and Gallt-y-Daren. The general arrangement of these fossiliferous strata on Bryn-pig, and from thence to the Cambrian rocks near Trawsfynydd, is well expressed in the Section, Pl. 28, No. 3.† Further north they occupy a wider space, rising and falling in anticlinal and synclinal curves in the country watered by the rivers Gain and Prysor, and two small bosses of Cambrian rocks reach the surface by a combination of curves, faults, and denudation. The larger patch is a mile and a half in length and from a quarter to three quarters of a mile in width. On the north and west the Lingula flags rest on it at angles of about 18°; on the south and east they are faulted against it. The smaller patch lies about three miles E.N.E. of Trawsfynydd near Castell-y-Prysor. On the east the Lingula flags rest on it at angles of about 30°, and, like the larger boss, it is also bounded on the south and west by faults. Notwithstanding these curves, however, south of the river Prysor the general inclination is eastward, but, beyond, the rocks begin to dip to the north-east and north, following, between Ffestiniog and the sea, the strike of the great anticlinal in its course towards the west.

It is in the immediate neighbourhood of Trawsfynydd that the dome-shaped Cambrian strata curve round to the west; for, while near the Trawsfynydd fault they strike nearly east, abutting on the Lingula flags, further west on the crags of Diphwys, and Y-Graig-ddrwg, they assume a north-east and south-west strike, and dip towards the Lingula flags of Traeth-bach and Morfa Harlech.

West of Craig-das-eithin ‡ the Lingula beds form a synclinal curve. The Cambrian rocks do not, however, crop from beneath their western margin, for the Trawsfynydd and Ffestiniog fault by a downthrow on the east cuts out both the Upper Cambrian beds and the lower part of the Lingula flags, so that on the east side of the great anticlinical, the apex of which lies south-west of Trawsfynydd, only about 1,800 feet of the Cambrian beds, roll towards the adjoining Lingula flags. The throw of the fault, therefore, near Trawsfynydd, cannot be less than about 2,400 feet. The evidence of the fault is perfect, since both formations yield a sufficiency of dips, and are seen to strike directly at each other. In many places along the road between Trawsfynydd and Tyddyn-du the Cambrian grits rise in thick shelving beds that dip a little to the west of north, at angles varying from 10° to 25° and rarely 40°.

Near Ffestiniog there are numerous Lingulæ in the grey flaggy ripple-marked

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* Six inch sections, Sheet 29, line 1.

‡ About 2½ miles S.W. of Trawsfynydd.

slates and grits in the river above and below Rhaiadr Cynfael, which, together with similar rocks by the town, are the general equivalents of the fossiliferous strata of Bryn-pig and Gallt-y-daren. On the same side of the Ffestiniog fault, further north, and a little higher in the series between Ffestiniog and the stream under Pengwern, the grits are fine grained, and somewhat spotted, talcose and flaky, and these, in ascending order, pass into the speckled beds (afterwards to be described) that occupy about a mile of country west of Manod-bach south of Careg-du.

Good sections of a high part of the Lingula flags occur further east near Llyn Treweryn, and in spite of the drift occasional patches of rock are exposed in Nant-y-lladron, Nant-y-groes, and on the shores of Llyn-y-dywarchen.* They consist generally of thin grey slaty beds, flags, and grits. Like those of Dolgelli, some of the slates are almost black, and the whole are more or less pyritous. At Llyn-y-dywarchen I found *Lingulella Davisii* in sandy flags with wavy rippled surfaces, and also in similar strata mingled with dark slates by Pont-y-lladron, Mr. Salter found numerous specimens of the same bivalve accompanied by ripple and Annelid markings. A little east of the bridge there are two quarries of thin bedded dark grey flaggy rocks, containing a small variety of *Lingulella Davisii* and Annelid marks:† and the latter also occur on the grits and slates that strike southward between the quarries and Carnedd Iago.

Many parts of the Lingula flags east and south-east of Ffestiniog are pierced by masses of greenstone, all much smaller than the broad-spreading rocks of Rhobell-fawr. They are especially numerous in the district between Afon Gain and the Ffestiniog and Bala road.

To describe each in detail would serve no useful purpose. The rocks in contact with them are often altered, and the greenstones have frequently been thrust between the beds. Without careful observation one might be apt to consider some of these as rising sheer through the strata, and as having a greater solid bulk than they possess. Some of them seem to be isolated sheets of greenstone resting on the slates, once connected with neighbouring masses, but since separated by denudation. Occasionally they are largely crystalline, hornblende forming the principal constituent, but in other cases (and these are generally less crystalline), they look so grey and felspathic that it is not without hesitation that they have been coloured with the greenstones, though in the very same mass these varieties often graduate into each other. The section ‡ crosses one of the larger and more solid looking bosses at Craig-das-Eithin,§ Fig. 3, pl. 28.

Tremadoc Slates and Llandeilo Beds.—The regularity of succession is somewhat interfered with by the faults south-west of Manod-bach, which for a space induce easterly dips, and help to throw the lower part of the speckled flaky beds eastward. Between Cae-blaidd and Manod-bach, the section is however more regular, and the Tremadoc slates and lower Llandeilo beds have been detailed by Mr. Salter in the following ascending order, beginning near the top of the true Lingula flags:—

"1. Light coloured hard spotted beds.—Lingula Flags.

"2. Spotted grey sandstones. "3. Grey sandstones indistinctly spotted. "4. Grey flags and granular sandstones. "5. Grey concretionary sandstones.	Upper Lingula Flags or Tremadoc Slates?
"6. Grey sandy beds, flaky, containing *Calymene Murchisoni* and *Asaphus affinis*. "7. Light spotted slate, and grey irregularly bedded sandstones, with numerous impressions of *Calymene Murchisoni* or *C. parvifrons*, *Ogygia Selwynii* (Pl. 9), and *Trinucleus*. "8. Thin bedded flaky slate, somewhat ferruginous, containing *Orthis Calligramma*." (Pl. 22.)	Lower Llandeilo beds.

* About 6 miles east of Ffestiniog.

† This is the place of the Tremadoc slate, but the peculiar fossils of that group occur further west.

‡ Sheet 29, line 1, Pl. 28, No. 3.

§ Two miles and a half S.E. of Trawsfynydd.

Between this and the felstone porphyry of the Manods there lies the thin slaty band already described.

Lingula Flags, &c., west of Ffestiniog.—In the upper Cambrian beds near Tyddyn-du the texture of the strata undergoes rapid variations. Some of the beds are coarse grits, with large oval grains of decomposing felspar. This passes into fine-grained, compact, hard grits, some dark, others lighter, with disseminated flakes of slaty matter that give a streaky aspect to the rock.

A strip of soft ground that lies between the Cambrian and the lowest of the Lingula grits is probably occupied by beds of passage, equivalent to those at Aber-rhamffroch near Barmouth.

Between Ffestiniog and the sea the Lingula flags are similar to those on the banks of the Mawddach near Dolgelli. Their general arrangement is shown in Pl. 28, No. 3.* The whole country, especially north of the river, has a rough and ragged appearance, caused by interstratification of hard siliceo-felspathic grits with softer slaty beds, the peculiar hardness of many of the strata being due perhaps to the toughly binding character of new silicates of soda and potash formed by internal decompositions and new combinations in the body of the rock. There is a strong resemblance in the outlines of the ground between the estuary of the Mawddach and the top of Cader Idris and Traeth-bach and Moelwyn, owing to the nature of the rocks being nearly identical.

With the view of determining the precise palæontological succession, the sections have been repeatedly examined by Mr. Salter, to whom I am indebted for the following minute detail respecting the strata between Ffestiniog and Tremadoc.

The lowest Lingula grits are well seen on the ground near Tafarn Helig.† They are hard, thick, and coarse, and generally more grey and softer than the Cambrian beds; but, like them, contain numerous angular and sub-angular grains of felspar. Other more flaggy and compact beds are associated with them, and those at the neighbouring lodge gate are succeeded by fine-grained grits that alternate with layers of thin bedded black ferruginous slate, jointed but not distinctly cleaved. A considerable thickness of black slate succeeds these alternations, and at the first sharp angle in the Avenue grits again appear, which, in their turn, are succeeded by a thick series of hard sandy grey beds, with rippled surfaces and *Annelide tracks*. Black slaty layers still occur in these, and the joints are full of oxide of iron. Above there are dark grey ferruginous slates, in which Mr. Salter found *Lingulella Davisii*, *Agnostus princeps* (Pl. 4), and *Olenus micrurus* sparingly distributed. In similar slate a little higher the surfaces are rippled, still marked by *Annelide tracks*, and full of the same *Agnostus*. Thin hard black ferruginous layers are more or less interstratified with these, good examples of which occur at Cae'n-y-coed, in the upper part of the village of Maentwrog, and at the waterfall where the beds are full of *Agnostus*.‡ This black slaty part of the series is probably about 1,300 feet thick, and occupies nearly half the ground between the Cambrian rocks and the river Dwyryd. The cleavage of all these rocks is imperfect. Overlying the black shales there is a thick series of compact sandstones as far as Maentwrog turnpike, with subordinate beds of slate containing trilobites and Annelide tracks.

Higher in the Lingula series at Tan-y-bwlch there are beds of flaky sandstones (with iron rust in the lines of cleavage), which alternate with a few thinner and more slaty beds. Similar strata occur at the west lodge of Plas Tan-y-bwlch and below Bryn-mawr, but more wavy in outline, and above them flaky beds containing small balls of iron pyrites. In the lower part of the garden quarry in front of Tan-y-bwlch Inn the layers contain *Lingulellæ* of all sizes; and the upper beds of harder grit exhibit a few *Annelide tracks* and burrows. Behind Bryn-mawr and Tan-y-bwlch there are fine-grained beds,

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* Also in 6-inch Section, Sheet 28, line 4.

† Where the turnpike roads branch to Maentwrog south-west of Ffestiniog.

‡ Mr. Salter informs me that immense quantities of *Agnostus princeps* (formerly believed to be the same as the *A. pisiformis* of the Swedish Alum slates) are to be seen in the rocks below the waterfall. Every flake of slate is crowded with their crushed impressions.

which splinter into pencils of 8 or 10 inches in length, and contain ***Annelides***, *Lingulella Davisii*, and *Cruziana semiplicata*. They alternate with hard bands of grit, and are succeeded by a bluish cleaved flaky slate, containing ***Lingulella Davisii***, much distorted by cleavage. A well-defined set of ferruginous slates rests upon these beds. When freshly fractured they are intensely black, but contain so much iron that its oxidation imparts a rusty hue to the rocks above the tramway, forming a distinctive and peculiar feature in the landscape, like the red hills on the banks of the Mawddach near Llanelltyd and Tyn-y-groes. This upper black slate can easily be traced, in spite of numerous small cross faults, from the turnpike road near the quay, across the tramroad above Bryn-mawr, and through the hills behind Tan-y-bwlch by Y-Dduallt (near which they have been worked for iron) towards the Ffestiniog fault. They contain on the tramway south of Tafarn-trip,* ***Dictyonema sociale***, and a species of ***Conocoryphe***, probably *C. invita* (Pl. 4).

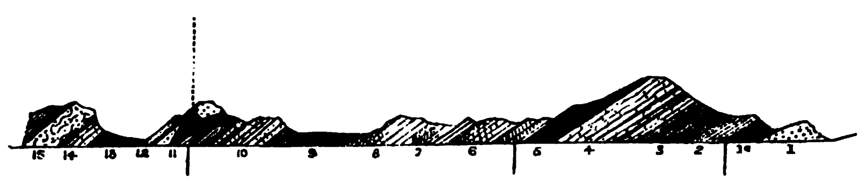
The base of the lower Tremadoc slate immediately overlies the beds described above, consisting of bluish slate, slightly ferruginous, and splitting into pencil-like fragments. It contains many small ***Lingulellæ***, and is much used in the walls of the neighbourhood. A hard compact grit rests on this, followed by thinner beds where the old Beddgelert road begins, above which are hard fine-grained speckled grits and flaky beds, mingled with a little ashy matter, about half a mile north of Tafarn-trip. On these lie the coarse quartzose grits of Bwlch-y-Maen of considerable thickness and about 10 miles in length, and about this horizon the lower Llandeilo slate, with genuine ashy interstratifications, begins.

Excellent sections of the Lingula flags occur on the ground between Maentwrog and Morfa Harlech. With some minor curves, they generally dip to the north-west at angles between 25° and 45°, inducing a characteristic series of sloping lines on the hills, that miles off indicate to the experienced eye the average inclinations of the strata. The beds correspond to those between Maentwrog and Tafarn-helig.

Concerning the promontory of Penrhyn, between Traeth-bach and Traeth-mawr, Mr. Salter has observed the following order in the strata, and has constructed a section across it.

Fig. 16.

DIAGRAM SECTION ACROSS THE PENRHYN PROMONTORY.



LINGULA FLAGS.

1. Micaceous light-coloured flaky sandstones. *Olenus*, *Lingulella Davisii.*
1*a*. Black ferruginous slate. *Orthis*, *Olenus*, &c. *Dictyonema* at the top.

TREMADOC SLATE.

2, 3, 4. Iron stained dark slates, with a thick series *above* them of hard blue rock, sometimes almost massive, with occasional beds of pisolitic iron, and with many lines of felspathic matter. (A few beds of the same nature lie below the dark slates.) *Psilocephalus innotatus*, *Niobe Homfrayi* (Pl. 6), with small *Lingulellæ*, and the *Dictyonema sociale*, are characteristic of it. [Lower Tremadoc slate.] Hills above Aber-ia, near Deudraeth.

5, 6. Slate with a pencil fracture, in thick beds, interspersed with hard, tough, and sandy layers, the same as those quarried for building at Portmadoc. *Asaphus Homfrayi* was found here (Pl. 8). The same beds rich in fossils at Tremadoc.

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* N.W. of Maentwrog.

7, 8. Alternating series of hard bluish flat-bedded slates and pencil slate (soft slate with a double cleavage, which breaks the rock into thin pencils); fossils rare. *Penamser*, Penrhyn-llwyd, &c. [The iron ore occurs in this series at Tremadoc.]

9. Soft thin bedded sandy shales. Marsh opposite Deudraeth, Minffordd, &c.

10. Hard bluish flags. Garth Hill, north side of west end of hill, and south side of east end, reaching to Deudraeth. Rich in fossils. See list in Appendix, *Angelina Sedgwickii, Asaphus Homfrayi, Cheirurus, Ogygia scutatrix* (Pl. 9), *Conularia, Orthoceras*, &c., with large specimens of *Lingulella Davisii*.

The greenstone penetrates these (10) beds somewhat obliquely, so as to lie on the chief part of them towards the east side, and under them on the west side.

Lower Llandeilo.

11. Thick grits, felspathic near the base. Garth Hill; no fossils.

12, Flat-bedded iron-stained black slate. Ty-obry; full of characteristic fossils. *Calymene Murchisoni, Asaphus affinis* (Pl. 8). *Dionide atra, Æglina caliginosa* (Pl. 11), with *graptolites*, &c. See Appendix.

13, 14, 15. Fine-grained bluish black slate, succeeded by ashy slate, and this by an ash bed, follow in the marshy ground to the north, and are the equivalents of the beds of Tan-yr'-Allt, on the opposite side of the estuary.

In tracing out the really simple arrangement of the beds in this insulated tract of country, the presence of the peculiar band of black and ferruginous slates is of great consequence. They can be traced by short traverses from the turnpike road, along its east side, in front of the hill farms of the Deudraeth. They come to the shore in considerable thickness at Abergafron, where they are highly contorted along a north and south line of fault, and, leaving the water's edge again at Borthwen-mawr, continue by Castell-Deudraeth to Aber-ia, where they are cut off by faults and turn north-westwards and reach the estuary at a cave near the east end of the embankment. Here they are seen to be overlaid in the pleasure grounds of Aber-ia by the dark earthy slates, No. 3, and these again by the harder beds No. 4.

These bluish hard beds (4), often a ribbon-slate, form the ridge of the country by Plas-yn-y-Penrhyn, and through the grounds of Castle Deudraeth, &c., and then are followed in the broken knolls that range towards Minffordd, by the pencil slate and its associated harder shales. The low marshy ground is occupied by the soft shales, No. 9, but no fossiliferous of beds consequence (though fossils are here and there met with) occur till we reach the higher heathy ground of Garth hill.*

The grit, No. 11, is from 400 to 500 feet above that of Bwlch-y-Maen.

Between the Ffestiniog and Trawsfynydd fault and the mouth of the estuary of Traeth-bach the Lingula flags are penetrated by numerous greenstone dykes, chiefly of a dark green colour, like the ordinary hornblendic varieties. They generally, but by no means universally, run in the line of strike, and as a rule entirely resemble other greenstone dykes in the same position on the east and south of the Merionethshire Cambrian strata.

Between the Cambrian grits and the syenite of Moel-tan-y-grisiau north-west of Ffestiniog the Lingula flags attain a thickness of about 5,000 feet. Above these are not less than 2,000 feet that may be Tremadoc slates. The whole, with slight exceptions, dip steadily north and north-west at angles varying from 20° to 40° or 50°. Pl. 28, No. 3.†

Underneath the sands of Traeth-bach the Lingula flags pass into the Tremadoc and Criccieth country. But before explaining the structure of that area it will be more convenient to describe the rocks that overlie the Ffestiniog syenite, and the igneous rocks of Moel-wyn and Cwm Orthin.

The syenite lies rather more than a mile north-west of Ffestiniog, and is about 2½ miles in length by nearly a mile in width. On the west it thins away to a point, and on the east it is bounded by the fault that cuts off the Cambrian rocks near Trawsfynydd. The whole forms a rocky moorland, strewn

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* The shells and trilobites of this rich locality are noted above.

† Section Sheet 30, line 4, and Map 75 N.E.

with its own fragments, and boulders from the neighbouring hills. It consists principally of a granular compound of felspar and quartz, with a sparing admixture of specks of poorly crystallized hornblende, and is by no means a fine specimen of its class. Up to its south-eastern edge the Lingula flags dip steadily towards it, and on the opposite side the strata seem in a measure to rest upon it, although both its nature and form preclude the idea of its being a bed of contemporaneous lava like the felspathic rocks in its neighbourhood. In some parts, too, the line of junction is broken and irregular, and round its margin the stratified rocks are highly altered. A good example of this occurs on the north of Cefn-trwsgyl, where the strata at the upper junction have been altered to the point that is difficult to define the precise limits of the stratified and unstratified material.

The rocks on the north-west and west of the syenite possess a character so singular that it is almost impossible to define them, the more so that on all sides they pass insensibly into those other varieties of stratified rock that form the mass of the neighbouring country. As a convenient distinction in the Ffestiniog district, they were called by Mr. Selwyn Upper Lingula flags, though in reality they belong to the Tremadoc and Lower Llandeilo slates since determined by Mr. Salter. In the joint description by Mr. Selwyn and myself they are said to consist of "grey and brown ashy and arenaceous flags, " often very felspathic, with thick bands of semi-crystalline felspathic ashes, " and bands of blue sandy pyritous slates." As a mass, it certainly does not deserve the name of ashes, and yet there is so much volcanic material intermingled with it that in places it is impossible to refuse it that name. Excellent sections are exposed on the hills on either side of the road leading from Tan-y-grisiau to Cwm Orthin, or from Glan-'r-afon-ddu and Ael-goch towards Llyn-trwstyllon,* but, indeed, the ground is so bare, rugged, and cliffy that almost anywhere between the Manods and the Beddgelert road, near Llanfrothen, the whole series is exposed. It is formed of beds varying from about a quarter of an inch to 2 feet in thickness; the thinner beds predominate. Being perfectly stratified, these rocks present a beautifully banded structure, rendered more prominent by the unequal decomposition of beds of different degrees of hardness. Their colour when fractured is bluish grey, curiously spotted or mottled like some honestones, or those rocks sometimes called variolite. These *pass into* a variety of rock composed of felspathic matter, speckled with hornblende, somewhat crystalline, but generally arranged more after the manner in which that mineral occurs in some varieties of gneiss, than in true crystalline rocks that have been melted. They cannot, however, be classed with the gneissic rocks, for this structure is exceptional, and the nature of the rocks is such, that their characteristics seem partly to belong to peculiarities of original depositions, partly to subsequent metamorphism connected with the occurrence of the neighbouring syenite. Some of the beds are talcose, and in general they are very fine grained. In some places thick beds of grey grit occur, as, for instance, by the road above half a mile below Llyn Orthin. In others the rocks are interstratified with irregular bands of blue pyritous slate; and indeed, the blue muddy matter used in the formation of the slaty beds is mixed in every possible per-centage with the more felspathic and talcose substances that form the main mass of this country. Especially towards the lower beds it would be easy to collect specimens showing a perfect passage into any of the varieties of ordinary flags on which it rests, and the same may be said of its passage into well-defined bands of true felspathic ash, such as those on the hills immediately above Llyn-y-garnedd, north of Tan-y-bwlch. Some of these ashes are porphyritic, this structure being probably due to the original mixture in the fine-grained matrix of broken and perfect crystals of felspar. Possibly, however, the unfractured crystals may have been partly formed by chemical decompositions and re-aggregations during or even subsequent to consolidation.

Being contorted, these ashes occupy a space comparatively broad, and the difficulty of mapping them is increased by the circumstance that ash, slate, and variolite wedge and pass into each other so rapidly that,

* Cwm Orthin lies 3 miles from Ffestiniog north-westerly, and Llyn-Trwstyllon close under the peak of Moelwyn on the south-east.

within 100 yards or so, the very same bed frequently entirely changes its nature, so that any boundary line must falsify so far the facts of the case. Finally, the ashy rocks almost entirely die away on the south-west before reaching the Beddgelert road, save where two small masses occur at Ynys-gwely and the hill south of Hirynys in Traeth-mawr. These, from their position above the sandstones of Garth,* must be in the Llandeilo series.

It is worthy of remark that a great change takes place in the lithological character of these rocks as they pass eastward, for their peculiarities disappear, not by the thinning out of the beds, but because they gradually lose much of their speckled appearance, and pass by insensible gradations into ordinary fossiliferous grits and slaty beds. Under the Manods, however, they are still in part distinctly speckled and talcose, and indeed traces of it occur as far south-east as the neighbourhood of Nant-y-lladron. From the true Lingula flags upwards the whole of this talcose series has been here and there pierced by greenstone dykes, some of which may be seen on the banks of the Orthin, and on the rocks on the north and east sides of Llyn Trwst-y-llon.

CHAPTER XI.

THE IGNEOUS ROCKS OF CAREG-DU, CWM ORTHIN, AND MOELWYN, AND THE STRATA BENEATH THEM.—THE LINGULA FLAGS AND TREMADOC SLATES.—THE BALA BEDS ABOVE THEM, AND THE GREENSTONES NEAR TREMADOC.

General Description.—The Moelwyn Range, &c.—North of Ffestiniog the felstones and ashes of the neighbourhood attain their greatest development on the two Manods, where the lower porphyry especially is of remarkable thickness. Westward of these mountains, on the rugged hills that overhang the entrance to Cwm Orthin, and on the eastern cliffs of the two Moelwyns, the interbedded porphyries, ashes, and volcanic conglomerates strike to the south-west, but beyond Moelwyn they become rapidly thinner, and finally die out altogether on the shores of Traeth-mawr. Below, the ashy beds are partly interstratified with slates, and above they are interbedded with dark blue slates of the age of the Llandeilo flags.

The rocks of the Moelwyns being identical in general position with those of the Manods, Llyn Conwy, and the Arenigs, it follows that the strata between Moelwyn and the syenite of Ffestiniog described in last chapter are the equivalents of the fossiliferous beds of Tai-hirion and the Manods, and proceeding westward along the line of strike across Traeth-mawr to the hills round Tremadoc, we find the same strata, with well marked groups of fossils ranging from a low part of the Lingula flags up to undoubted Bala beds.

The vertical throw of the north and south fault that skirts Manod-bach is probably not less than about 2,000 feet, for the rocks dip north at considerable

* For the fossils of Garth, *see* p. 69.

angles, and the whole country is thrown down and forward on the east, so that the lower margin of the Manod porphyry is separated more than a mile from Careg-du, its equivalent on the west side of the dislocation. The Ffestiniog and Trawsfynydd fault is also a downthrow on the east of about equal amount in this neighbourhood, and two minor cracks lie between them, the principal of which affects the felstone porphyry, and is a downthrow on the west. This arrangement of the strata is due not to the masses having been thrown by successive steps *forward* to the south, but is the combined result of downthrow and denudation.

The Careg-du* porphyry corresponds to that of the Manods. It is of the ordinary felspathic kind, and in places columnar. A thin band of altered slate underlies it, visible above the road near the southern margin of the felstone. Speckled beds underlie this slate, and both correspond to the strata that crop from beneath Manod-bach. North of Careg-du two very thin felspathic ashy bands occur in the slates, the whole corresponding to the rocks of the slate quarries already noticed between Moel-bywydd and Llyn-du-bach.† On the west the porphyry *abuts against* those talcose and speckled beds that *underlie* it on the south. This is the result of a downthrow on the east along the Trawsfynydd and Ffestiniog fault. There can be no doubt, then, that the felstone cliff, a little south-west of Tal-y-waunedd (on the west side of the fault near its northern end) is the equivalent of the masses of Careg-du and the Manods, and this rock, with two small interruptions, is continued southward as far as the broken slopes on the eastern side of Moelwyn-bach.

North-east of the stream that flows from Llyn Orthin above the brook and tramway, the lowest of the igneous rocks consists of a thick mass of felspathic ashes and conglomerate. Near the Ffestiniog and Trawsfynydd fault it is hidden by the rubbish of the slate quarries, and on the west, before reaching the stream, it either thins out or passes imperceptibly into the speckled rocks already noticed. The agglomerated fragments are both rounded and angular, more generally the latter, and it then becomes a sort of scoriaceous felspathic breccia. It is succeeded by a thin band of slate, which separates it from the felspathic slaggy-looking porphyry that lies between the conglomerate and the slate quarries. This abuts against the fault, near Tal-y-waunydd, and from thence, passing about half a mile to the south-west, it is interrupted by a short dislocation, and then, after a natural break in continuity of about 100 yards, it re-appears, and striking westward crosses the valley of Cwm Orthin, a little below the lake, resting directly on speckled flags. The band of slate, however, that elsewhere separates it from the underlying rocks, very soon re-appears, and both pass south-westerly, crossing the stream that flows from Llyn Trwst-y-llon immediately below the lake, and finally the porphyry ends about half a mile farther south. Its average thickness is from 300 to 400 feet. Its position on the right of Llyn Trwst-y-llon, and that of the underlying thin band of slate, are shown in the section, Pl. 28, fig. 3.‡ The slate that rests on it is unaltered, while that underneath is often porcelanized, and this, in addition to structure, helps to indicate its origin; viz., that it was poured in a melted state upon the muddy sea-bottom, and had cooled before the deposition of the unaltered layers that rest on it. I have (p. 65) identified it with the porphyry of the Manods, for its position with reference to Careg-du on the opposite side of the fault proves this. They underlie the same beds, and the same thin band of slate may be traced under all these equivalents, from Llyn Trwst-y-llon to the Manods.

This line of felstone is overlaid by another set of volcanic ashes and conglomerates, which pass from the country east of the outflow of Cwm Orthin, through Llyn Trwst-y-llon, and end a little south of the lake.§ Like the

* About 3 miles north of Ffestiniog.

† See p. 55.

‡ Also 6-inch Sections, sheet 28, line 3.

§ Marked "felspathic ash conglomerate and breccia," in the 6-inch section, sheet 28, line 3. The other band of volcanic conglomerate, that beyond Cwm Orthin, underlies the thin band of slate beneath the "slaggy grey porphyritic-felspar trap," does not occur in the line of the section.

lower mass it is sometimes brecciated, the included fragments being mostly felspathic, and of all sizes, from a mere grain to nearly a foot in diameter. Rarely it contains rounded pebbles of quartz. A band of slate under Moel-y-rhudd rests on this conglomerate. It has been quarried for roofing purposes, but never can be worked effectually, owing to its thinness, and the high angle at which it dips under the immense overhanging mass of the porphyry of Moel-y-rhudd. Towards Llyn Trwst-y-llon a bed of porphyritic felspathic ashes of about 150 feet in thickness wedges into this slate. It lies on the left of the lake. By means of a series of faults it appears on both sides of Moelwyn-bach, the whole summit of which is much dislocated, the fractures being filled with large veins of quartz. It ends about Hafod-uchaf, near the old road to Beddgelert, and all along its course it is distinctly bedded and porphyritic, crystals of felspar being embedded in a compact blue felspathic base. Above it are beds of slate about 150 feet thick, and these are succeeded by a felspathic lava bed, about 900 feet in thickness, that runs from Cwm Orthin, along the slope between Llyn Trwst-y-llon and the summit of Moelwyn. Like the other true felspathic lavas of this range it is more or less porphyritic, and often rudely, and sometimes perfectly, columnar.

On the summit of Moelwyn, resting in the felspathic trap, are blue Llandeilo slates* (Pl. 28, fig. 3), equivalent to those in the quarries of Cwm Orthin and the other great quarries further east. Thin inconstant felspathic and talcose bands containing crystals of iron pyrites occur in these, some of them passing through the quarries on the west of the Ffestiniog fault, and reappearing on its opposite side between Cribiau and the porphyry of Craig-du. These and some other thin layers on Moel-y-rhudd are now in a distance of 12 miles the sole representatives of the 800 feet of ashes that lie on the east slope of Arenig, and spread northward from thence to Llyn Conwy.

Moel-y-gest.—I shall now give the section of the Lingula and superincumbent beds between the hills behind Tremadoc and the coast at the mouth of the estuary. These beds round Moel-y-gest and south-west of the Tremadoc greenstones, have been generally described by Mr. Selwyn as dark blue shivery slates, often ferruginous, here and there interstratified with arenaceous flagstones, and thin grey grits bearing *Lingulella*. On the road from Tremadoc to Criccieth they dip north-easterly; and he considers them continuations of part of the rocks under Moel-y-gest, and equivalent to those on the road from Maentwrog to Harlech. The remaining observations on the ground near Tremadoc are partly from personal observation, but chiefly from details communicated by Mr. Salter. It quite corresponds with the other sections near Ffestiniog.

"The lowest beds of the mass of Lingula flags to be seen on the road to " Criccieth are at Ynys Cynhaiarn, where the strata arch over, dipping north-" east and north-west; but by proceeding south to Treflys and the coast,† " the Lower black slates are seen, and Morfa Bychan is occupied by a " ferruginous part of the Lingula beds equivalent to those that lie south of " Maentwrog and Ffestiniog; they contain *Lingulella*, *Agnostus*, and *Olenus*; " and they are succeeded by hard sandstones and grits, with fine grained and " flaky grey slate, containing crustacea, *Lingulella Davisii*, in profusion, and at " one locality, tracks of *Cruziana* on their sandy widely rippled surfaces, " *see* Pl. 3. These sandy beds are often micaceous and grey coloured, striped " with whiter bands, very few of the upper beds being coarse grained. *Lingu-" lellæ* are also found at Bron-y-foel; *Hymenocaris* and *Lingulella* at Careg-" felen, at the entrance of the lane to Y-wern; also at Bryn-twr summer " house; and especially on the hill descending to Penmorfa Church, the shells " are most abundant. Borth, a mile south of Port Madoc, is a good locality " for all these fossils.

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* Map 75 S.E.; Section, sheet 28, line 3.

† A fine section of these Lower black slates is visible at the caves of Y-Graigddu, between Treflys and Criccieth. The beds are much contorted, overlaid by the whole mass of the Lingula sandstones, and again covered (proceeding towards Criccieth) by the Tremadoc slates and Llandeilo flags in regular succession.—J.W.S.

"The grey micaceous slate is very little affected by cleavage in this middle "part of the series, the layers thin and wavy, and in part full of patches of "drifted sand with broken and entire shells. The marks of Annelides cross "obliquely, sometimes under, sometimes above, the surface, and are either in "relief or intaglio. When the latter, they have sometimes a raised edge, as if "pushed up on either side. The solid tubes appear to have been the contents "of the intestinal canal, for the sand is of different texture, and generally "coarser than the surrounding matrix. Details of the mode of occurrence of "these tracks, which have been observed in situ, are given in the Appendix, "where, too, the localities explored by myself and our own collectors, or by "our friends Messrs. Ash and Homfray, are enumerated (*see* page 245).

"The higher part of these beds is a smooth grey slate, and on the rising "ground north-west of Penmorfa Church, it is literally crowded with *Lingulella* "*Davisii*. It is the equivalent of the beds previously described immediately "behind Bryn-mawr and above Tan-y-bwlch, and other places along the "Ffestiniog valley. The whole represents closely, both in lithological character "and organic contents, the beds near Dolgelli."

Tremadoc Slate.—"These, by Penmorfa Church, are thin bedded, fine "grained, blueish glimmering slates, with ferruginous partings and imperfect "cleavage. They are succeeded by black ferruginous slates, which, however, "are here by a fault less exposed than the same beds near Maentwrog. Here "and there striped layers show alternations in the sediment, and just under the "church, contain *Conocoryphe invita*, *Olenus alatus* (Pl. 4), *Agnostus princeps*, and "*Lingulella lepis*, besides numerous impressions of *Orthis vaticina*, observed in "these strata for the first time. On the east side of the S.S.E. fault at Bron-y-"foel slate quarries, and at Y-wern they are lost, the Lingula flag being "succeeded by the Tremadoc slate. The true, lower, sandy Lingula flags abut "on these on the west of the fault that runs S.S.E. from Y-Wern, but are "followed regularly along the south side of Moel-y-gest and through the "woods of Borth, first by the black upper Lingula flag, with its characteristic "trilobites, and then by the Tremadoc slate."

On the north side of Moel-y-gest there is a fault striking E.S.E. It is a downthrow on the south, repeating on the north slope of the hill the beds about Tremadoc. The underlying grits have been altered, and the whole strata of the hill overlaid by greenstone dips northerly from 14° to 45°. An iron ore occurs on its slope immediately north of the edge of the greenstone, by which its beds are easily identified.

"On the north side of the fault there are beds of grey, sandy, thin-bedded, iron-stained slate, sometimes striped. They rest upon the upper Lingula flags, and on the other side of the marsh are of considerable thickness in the lane that leads north-east from Penmorfa Church to the Caernarvon road, where they dip a little north of east. They are also well shown on the new road from Penamser to Port Madoc, and are everywhere easily distinguishable by their very thin bedded character, and their containing more iron than the upper part of the sandy lower Lingula flags N.N.W. of Penmorfa Church. They are soft in texture, and the iron stains occur both in the lines of bedding and in those of imperfect cleavage. This fault, according to Mr. Salter, is one of many small faults which complicate this district, and it does not much affect the beds west of Penmorfa. The loss is made up by consulting other sections.

Along the line of the new tramway which runs from Tremadoc to Brynkir, the Lingula flag and overlying black slate are seen to be followed by precisely the same succession of beds as that given for the Penrhyn promontory, p. 62, viz., iron-stained dark earthy slates, harder and greyer beds, with felspathic lines (often a ribbon slate), followed by softer beds, before reaching the hard sandstones that range under Yr-alt. The series south of Moel-y-gest is even more clear, the hard bluish grey beds being still more indurated by the protrusion of the greenstone, which is on a lower level than that of Tremadoc. At Borthwood the best section of all is seen, and the black slate full of primordial trilobites is followed at once by the iron-stained thin beds, which, indeed, occupy the whole area from Borth harbour to the south flank of Moel-y-gest. Their lowest layers contain only the *Dictyonema sociale*, but a hundred feet higher they are rich in trilobites, *Psilocephalus* and *Niobe* (see Appendix), together with Theca and the small *Lingulella lepis*. The numerous S.S.E. faults

[redacted]

render it difficult to trace any set of beds continuously. The entire section, however, along the cliff to Port Madoc shows a fine series of the pencil slates (Upper Tremadoc), and the large quarries are opened in their upper portion. A thin lenticular bed of ash along the crest of the hill from Morfa Lodge conducts us to the fossil locality of Tu-hwnt-yr-bwlch, whence Messrs. Homfray and Ash have obtained nearly all the Upper Tremadoc fossils; as these are known in the corresponding beds of Garth on the opposite shore, *Ogygia, Cheirurus, Asaphus, Conularia, Orthoceras,* &c. &c., there can be no difficulty in identifying the two sections. The same beds are less perfectly seen ranging along the Tremadoc escarpment under the greenstone and above the iron-works. These very thin-bedded flags occupy all the hill about Tyddyn-dicwm. They are somewhat ferruginous, obscurely cleaved, and contain *Asaphus affinis.* At the top are soft blackish layers; and these are succeeded by very thin bedded, light, grey, and black slate. The same beds occur on the road from Penmorfa to Tremadoc, and above Tremadoc itself, and, both from position and fossils, are evidently nearly on the same line as the soft beds of slate at Plas-newydd and Minffordd on the opposite shore."

Lower Llandeilo beds.—Above these is a bed of slaty pisolitic iron, near the top of the hill that overlooks Tyddyn-dicwm, and this is succeeded by fine-grained pale sandstone, studded with cubes of iron pyrites lying all along the hill under and in places also above the greenstone of Penmorfa, by which it is partially altered. It contains many *Annelide tracks.* A N.N.W. fault runs between Penmorfa and Yr-Allt-wen, repeating the greenstone and grit and pisolitic iron ore. The grit is altered and somewhat speckled like the beds towards Ffestiniog. These rocks strike from Yr-Allt-wen to Tremadoc, where some minor faults occur. They are then lost in the alluvium of Traeth-mawr, and reappear on the north side of the greenstone of Garth, where they have been already described.

"Above Tremadoc the grits pass through concretionary blueish slates into " the dark grey or black slate of Cwm-mawr, on which rests black slate, with " felspar crystals, which passes into a flaky felspathic ash bed, that runs for " nearly 2 miles north-west from the marsh at Tan-yr-allt." This is the equivalent of the bed of ash that forms the hill south of Hir-ynys, on the opposite side of the river, and the strata are, therefore, the equivalents of the beds of Llyn Trwst-y-llon and the south slope of Moelwynbach. " On the Tremadoc side of the estuary the ash merges above into ashy " slate, with concretionary grains, which is succeeded by the highly crystalline " greenstone of Bwlch-y-moch, which alters the rocks both above and below. " Those above consist of hard felspathic, fine-grained, spotted flags, with " *Annelide trails,*" well seen at Porth-treuddyn, and are probably partly represented by the ashy boss of Ynys-gwely in the marsh a little north of Hir-ynys.

Though apparently these greenstones often for a long space adhere rigidly to the line of strike, they are certainly intrusive, for the rocks have been equally hardened by heat, both below and above, a circumstance that gives them a value as flagstones, for which purpose they have been extensively quarried between Bwlch-y-moch and Porth-treuddyn, and also near Yr-Allt-wen. The flags are mostly of a light grey colour, and look as if partly composed of felspathic matter, a circumstance that may have aided in their alteration during the intrusion of the melted greenstone. Mr. Selwyn remarked, that in some places they looked as if crystallization had commenced.

Above this are blue slates equivalent to those of Moelwyn, Cwm Orthin, the Ffestiniog slate quarries, and that part of the Llandeilo beds generally that immediately overlies all the felspathic porphyries and ashes that range from thence to Arenig and the Arans. Still higher there are the sandy slates and grits of Mynydd-y-gorllwyn, which Mr. Selwyn and Mr. Salter found well charged with the ordinary Bala fossils, both here and north-east of Ynys-wen.

CHAPTER XII.

RECAPITULATION AND SUMMARY.—CAMBRIAN, LINGULA, TREMADOC, AND LLANDEILO ROCKS, &c.—SLATE.

I HAVE now described in detail the structure, distribution, and succession of the rocks of a large part of Merionethshire, beginning with the Cambrian grits, and passing across the intermediate strata into a low part of the Bala beds. Before proceeding further I shall sum up the results.

First, then, Lingula beds, Tremadoc slates, Llandeilo flags, and igneous rocks enclose the Cambrian rocks on the south, east, and north in a crescent-shaped curve, the greatest diameter of which from south to north is about 22 miles. Their average dip is outward from the Cambrian centre. The principal component parts of the stratified (or ashy) and interbedded porphyritic portion of the igneous rocks that lie above these is exceedingly simple. On first entering the country, however, one might be apt to suppose that it is formed of greenstones and felspathic rocks, slates, and grits mingled in inextricable confusion, and that its igneous components at least treble in amount what they are in reality; but after all the faults have been disentangled, and every lava-current, as far as the scale will allow, has been carefully mapped, they resolve themselves (eliminating the intrusive greenstones) on the south and south-east into one thick set of beds of felspathic ashes and conglomerates mingled with strata of slate, and overlaid by masses of felspathic porphyry.* Where tilted at a high angle, as in the Aran range, these together are about a mile in breadth, but in other places they cover broad tracts of country, where, partly by undulations and partly by repeating faults, they spread over spaces of 4 or 5 miles in width. Except where broken by faults, the felspathic porphyry is continuous from Cader Idris to Llyn Serw, 5 miles east of Ffestiniog, when it disappears for a time, but again comes on in the Manods and Careg-du, and from thence strikes westward to Llyn Trwst-y-llon. The ash also except where faulted is continuous from near Llanegryn, 6 miles south of Barmouth, to Moel-llyfn-nant, 6 miles west of Bala Lake, where it ceases for a space, partly perhaps by thinning out, and partly by the gradual passage of felspathic into what were muddy and sandy sediments, and this passage is often evident on the ground, though it is impossible to express it on the map. Thin ashy streaks also here and there are mixed with the slate beyond Moel-llyfn-nant; and in the neighbourhood of Ffestiniog, in the same parallel, beds more or less ashy, again come on between Llanfrothen and the Manods, which also in their turn, merge in the strike into

* At first it was impossible to separate all the varieties of igneous rocks, and the maps of this area were published with all the igneous rocks of one colour. Subsequently however my experience in the Snowdon district, proved the practicability and value of separating all the varieties, and additional lines were accordingly run in Merionethshire by Mr. Selwyn, Mr. Aveline, and myself, and added to the maps.

ordinary sediment, charged, both there and further west, with Llandeilo fossils. The great mass of felstone that overlies this ash begins near Penmaen (2 miles and a half south-west of Llanywchllyn) to be overlaid by a second set of felspathic ashes and conglomerates, which, passing northwards, attain a thickness of about 800 feet in the Arenigs, and thin away again in the Ffestiniog slate quarries. Llandeilo and Bala beds everywhere overlie these rocks, and, as I have explained, rocks holding Llandeilo fossils also underlie them at Tremadoc, Garth, under the Manods, and at Tai-hirion,—a fact first discovered by Mr. Salter, and further proved by the determination of the precise parallel of the bedded igneous rocks that rest on them, by Mr. Aveline and myself. If then, as I believe, the grit of Garth,* the speckled beds east of Moelwyn, the Manods, the Carnedd Iago grits, and the Tai-hirion slates, are in part the equivalents of the ash of Cader Idris, the Arans, Moel Offrwm, and Moel-llyfn-nant, then *the whole of the lower interbedded igneous series is included in the Llandeilo beds.* Lower on the north there seems to be a passage into Tremadoc slates, beneath which lie the Lingula flags.

There is another point well worthy of remark, which is, that if we follow these contemporaneous igneous rocks along their strike westward, both from Cader Idris and Moelwyn, we find that they gradually die away and dissappear on the south towards Llanegryn, and on the north a little beyond Tremadoc†. The lower ashes attain their maximum under Cader Idris and Aran Mowddwy, and rapidly thin away on the north and north-west at Moel-ddu and Y-Dduallt. They are gone under Arenig and imperfectly developed under Moelwyn. The felspathic lava or porphyry is also thickest on Aran Mowddwy, and though largely developed on Cader Idris, its true contemporaneous nature is there in places uncertain. The upper ash attains its greatest thickness about the Arenigs, and thin away entirely on the south near Penmaen, and on the north by Cwm Orthin. Following its strike, it is found to be a lenticular mass of about 23 miles in length by 800 feet thick where thickest, and for the felspathic porphyry and lower ash there is good evidence that each was continuous across a diameter of at least 22 miles, and probably much more, for though they do not not rise in the outcrop of the Bala and Lingula beds north of Snowdon ‡ (Pl. 28, No 3), yet they must continue underground for some distance in that direction. It is hopeless to guess how far the individual beds extend beneath the encircling Bala slate on the east and south-east, although we know that rocks on the same general parallel crop out in the Berwyns and at St. David's.

If on the data obtained by means of the sections that cross

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* On the east side of the estuary of Traeth-mawr.

† It will afterwards be shown that the igneous rocks of Llwyd-mawr (75 N.W.) are of later date.

‡ Section, Sheet 28, line 2, and Map 78 S.E.

this country we tabulate the thickness of the greater masses of rocks, they are nearly as follows:—

—	Cader Idris.	Aran Mowddwy.	Moel-ddu.	Y-Dduallt.	Arenig.	Moelwyn.
Upper ashes and volcanic conglomerates - -	Feet. 100	Feet. Traces	—	Feet. —	Feet. 800	Feet. —
Felspathic traps -	2,850	2,400	1,150	1,200	250	If same, 400.
Lower ashes and volcanic conglomerates - -	2,700	3,400	1,100	1,300	0	Representative beds occasionally ashy, 2,700.
Lower Llandeilo beds, Tremadoc slates, and Lingula beds - -	6,750	6,000 No base.	No base.	7,000	7,000 ?	7,000
Cambrian - -	6,000 to 7,000. Base unknown.	—	—	No base.	No base.	4,000 Base unknown.

It thus appears that, aided by the repetitions consequent on the Bala and Tai-hirion faults, we are in a condition to prove that in the short space of 5 miles the felspathic trap has thinned 2,000 feet, and the ashes have nearly quite disappeared in their progress westward. This increases the probability that, before the denudation of the country had removed the Silurian rocks from above the Cambrian dome, the contemporaneous igneous rocks of the Arenig and Dduallt ranges did not stretch westward in continuation of their present outcrops, beyond the existing terminations of their north and south horns at Tremadoc and Llanegryn. There is, therefore, no likelihood that the volcanic centre was in the Cambrian region, for its principal igneous rocks are mere greenstone dykes, and the larger erupted patches, near the centre of the Cambrian anticlinal, are small in size, compared with others that break through the Silurian strata. The volcanic centre or centres of this series were, therefore, probably to the eastward of a line drawn between the points where the volcanic rocks thin away near Tremadoc on the north and Llanegryn on the south, and some of the felspathic masses that break through the Silurian strata may perhaps indicate the position of volcanic centres, or in other words, portions of the melted matter situated *beneath or in* the necks of volcanoes while in action, as, for instance, the erupted felspathic masses of Tyddyn-rhiw and Gelli-llwyd-fawr south-west of Dolgelli, and of Y-Foel-ddu, near Aran Mowddwy, and possibly of part of the Arenig if any of it be intrusive. It is worthy of remark that in the neighbourhood of these rocks near Dolgelli and Aran Mowddwy the lower ashes and felstones attain their greatest development; the thickest part of the upper ashes is near Arenig, and north west and east of the Ffestiniog syenite, which is very felspathic we have the thick interbedded porphy-

through the ashes, which, therefore, may in part at least een ejected from some other vent.

ides these (irrespective of the dykes) there are numerous d masses of greenstone, one of which, that of Rhobell-fawr, er and more central than any of those of more felspathic al lately enumerated; and it may be asked whether or not f these might not have formed centres of eruption. If so, oes it happen that the great contemporaneous lava beds little hornblendic? It is certainly the case that some of greenstones seem to contain more felspar than hornblende, ey may be said invariably to be far more hornblendic ny part of the great lava currents, which only in a few es for a little space might doubtfully be entitled to the ation of greenstone, and it is, therefore, more than impro- that a deep-seated mass, which, when cooled, crystallized reenstone, should have overflowed in lava beds of purely hic quality. Their ingredients are different, and in no case in Merionethshire is there any line of greenstone that proved to have flowed across the surface. There may be lt and doubtful cases, and there are many in which a cursory nation would recognize no difference between their mode of ence and that of the felspathic lavas, but a thorough ntance with every yard of the igneous rocks of Merioneth- will show that in no single instance is it safe to include any greenstone in the list of lava currents, and in most of them nay safely be dismissed from that category. Nevertheless, ot the less certain that they are intimately connected with lcanic phenomena of the district, for it will be observed that them lie either *among or beneath* the felspathic porphyries hes, or in the case of most of the greater masses, among the la flags themselves. They are, in fact, never found in the eds of Merionethshire that overlie on the south and east the edded igneous rocks, and where they occur in the Bala rocks, en Ffestiniog and Llanberis, it is under circumstances which, be shown, bear the same relation to a later set of volcanic phe- a that the greenstones of the Lingula flags do to the felstones hes of Merionethshire. One of those difficulties that occa- y arise with regard to these greenstones is somewhat remark- nd consists in this, that they sometimes seem to occupy the f some of the ashes. Thus, for instance, at Craig-y-Benglog* hes, as it were, strike directly at the greenstone, which, being ive and branching, might be expected to squeeze out and side the strata. This it does not do, and analogous cases on Cader Idris, where thick and decided greenstones running line of strike, do not appear to thicken the general mass of in these particular localities. However strange it may , this circumstance almost induces the belief that these tones have been formed by the melting of a part of the amid which they lie. Taking the greenstones as a whole, all

* About 6 miles N.E. of Dolgelli.

I can definitely say about them at present is, that the common and obvious explanation of their mode of occurrence would seem to be that during the time of volcanic energy the matter that forms some of them was burrowing hither and thither in the bowels of the volcanic district; while the fact that many of them seem to replace missing portions of the strata would seem to point to the circumstance that they have been formed in place by the fusion of these strata themselves. Under either hypothesis, why the melted matter did not sometimes reach the surface and overflow, I cannot explain.

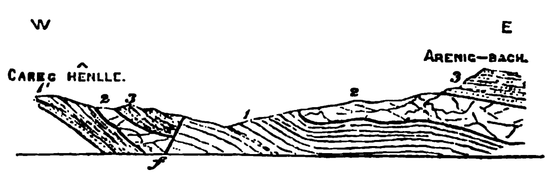
Fossils of Garn, Tai-hirion.—The following remarks show the relation of the Tremadoc slates, Llandeilo flags, and Bala beds to the Lingula flags already described. Between Cader Idris and the Machno I am not aware that fossils have been found in the slates that rest *immediately* on any part of the igneous series. But near Garn, four miles north-west of Bala, I found in the year 1847 certain fossils in coarse black slates faulted against the igneous rock by a downthrow on the south. The fossils are, however, from beds which, omitting the interbedded ashes, would not be far above the horizon marked No. 1 in fig. 11, and consist of the following species, determined by Mr. Salter: *Orthis Actoniæ, O. biforata, O. insularis, Strophomena spiriferoides, Leptæna quinquecostata, Stenopora fibrosa, Bellerophon bilobatus ?, Ischadites, Ampyx mammillatus*, with species of *Asaphus ?, Cybele, Lingula, Ctenodonta, Orthoceras*, &c. (see Appendix). Most of these are Llandeilo species, and all of them range into the Bala beds except the *Ampyx.*

Immediately *underneath* the bedded igneous rocks near Tai-hirion, Mr. Salter observed in coarse black slates with grains of sand, hard grey and striped sandy slates, and soft, black, earthy slates, the following species in the slates marked No. 1, fig. 16: *Ogygia Selwynii, Calymene parvifrons, Orthis calligramma, Diplograpsus pristis*, with imperfect specimens of *Agnostus, Asaphus, Angelina ?*, and *Theca.* The grouping is that of Llandeilo beds.

The following section explains the arrangement of the rocks near Tai-hirion.

Fig. 17.

SECTION FROM ARENIG BACH TO CAREG-HENLLE.



1. Fossiliferous Llandeilo slate.
2. Felspathic porphyry.
3. Felspathic ash.

The slates marked 1′ are the equivalents of the fossiliferous slates No. 1, which are near Tai-hirion, and in the strike of these

beds, about 2 miles to the north-west at Carnedd Iago, there are three beds of grit and a thin ashy band immediately underneath the felspar porphyry of Cerig-y-bala. These grits are highly felspathic, and it is extremely probable that they actually represent a portion of the lower felspathic ashes of Cader Idris and the Arans, more especially as there is a thin band of the latter a little south of the Bala road that occupies the same general horizon. On Carnedd Iago, in Lower Llandeilo beds not far below the Arenig porphyry, Mr. Salter found *Asaphus affinis?* and *Orthis calligramma*; and further down I found *Lingulella Davisii* in undoubted Lingula flags at Llyn-y-Dywarchen.*

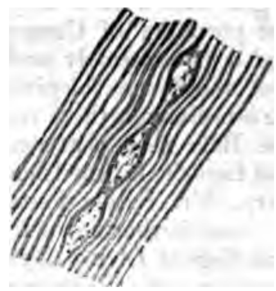
We have therefore, in this neighbourhood, evidence of the succession of life on three horizons. First at the base lie the ordinary *Lingula* flags, above which are strata containing *Agnostus* and *Ogygia*, associated with an *Asaphus, Graptolites*, and *Orthis calligramma*, and above the traps fossils which range upwards into the heart of the Bala beds or Caradoc sandstone. The lower strata were deposited before the commencement of those volcanic outbursts that spread over the sea bottom of this area hundreds and in places thousands of feet of volcanic ashes and streams of molten lava.† The fossils in the third horizon above the igneous series are genera and species common both to the Llandeilo and Caradoc or Bala beds, and in all the strata above the Lingula flags the brachiopoda of this district are common to the Lower Silurian rocks generally. The disturbances, therefore, that accompanied the igneous outbursts had nothing to do with any change of the life of the time.

Slate.—With a few remarks on the slate of this part of the Silurian beds I shall conclude. In the Ffestiniog slate quarries interrupted bands of grey greenstone pierce the slates in a remarkable manner, sometimes seeming to lie between the beds, sometimes between the planes of cleavage, and often coinciding with neither. In the great quarry west of the Ffestiniog and Trawsfynydd fault the cleavage dips from 45° to 50° north-west, the inclination of the beds being about 35° in the same direction, and a greenstone dyke runs through them between the cleavage planes in the manner shown in the following diagram, bulging and thinning off in a rapid succession of oval-shaped masses of 3 or 4 feet in length. Associated with it are quartz veins occurring principally at the points between the separate bulgings of the greenstone. In another case in the same quarries a large grey kidney-shaped mass has been exposed. It is somewhat amygdaloidal, and its vesicles are filled with quartz or with carbonate of lime coated with quartz. It is certainly one of the original edges of a dyke that never saw

* Four miles east of Ffestiniog.

† The same assemblage of fossils is found in beds that lie low in the Llandeilo flags near the Stiper Stones, and these horizons are both lower than any of the strata that rise in the dome of the Berwyns, or in the Llandeilo flags of Caermarthenshire. In Pembrokeshire they may be looked for.

Fig. 18.

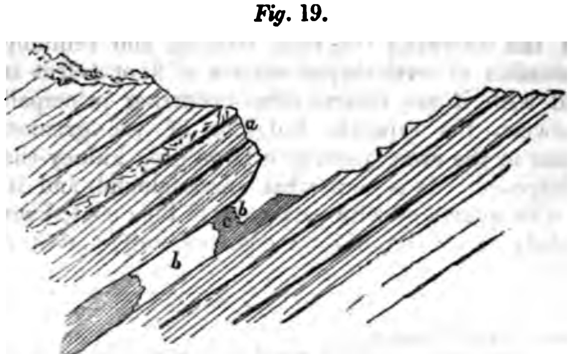


the light till laid bare by denudation, and the operations of the quarrymen.

It is not to be supposed that the greenstones are in this region all precisely of one date, but for many reasons it may be considered certain that the majority of those *that lie more or less between the beds* were injected in Lower Silurian times, in which case they were of prior date to the greater disturbances of the rocks, and consequently to the development of the cleavage of the country. This, however, is not invariable, for it will be shown that in Caernarvonshire some of the common *vertical* dykes include fragments of cleaved slate. These I believe were injected at a much later date. In the case of the greenstones described (diagram 18), it appears that being injected nearly in the lines of bedding, and the forces that caused the cleavage having produced it nearly in the same plane, the igneous rock has interfered with the regularity of the cleavage, which near the greenstone assumes a wavy instead of a rectilinear character.

It is to modifications on a large scale, induced by change of lithological character, cleavage, joints, dip, and position of the strata, that the availability of the same set of beds for slate making depends in different localities. Thus in one of the Ffestiniog quarries the rocks lie nearly as follows:—

Fig. 19.



A large quantity of slate has first been quarried from the surface, but as the strata dip north about 35°, and as the hills also

rise behind the quarries in that direction, the top *a*, which consists of weathered and valueless slate, is so thick that it will no longer afford the expense of removal, and consequently the quarriers have for long followed the profitable bed *b* on its dip by an excavation, which, as the work proceeded, increased in length and depth. The roof is supported by pillars *c* of slate left for the purpose, and the day will come when, following the dip, the workmen will reach a depth too great for the profitable continuance of the work. The pillars form a fertile source of anxiety, for they have sometimes given way and slipped in the direction of the dip, large masses of rain falling in on the workings. The foregoing instance makes it evident that much depends on the size and form of the "top;" and if the beds dip and the surface of the country slope in the same direction, they lie advantageously for working, for the quantity of "top" *a* may not be so much increased but that it may be entirely removed. Many other cases may be cited, but these form two of the more typical instances of the manner in which the same beds are affected by the form of the ground in the locality of the Ffestiniog slate quarries, without reference to other conditions, such as the presence of multiplicity of joints, imperfections in the cleavage, or other changes in the structure of the rock. There can be no doubt, for instance, that the strata by Llyn-bywydd are identical with those of the large quarries between that pool and the Manod-bach fault; but the beds of slate east, west, and south of the lake are thinner than at the quarries, and the interstratified ashes and conglomerates have greatly increased in thickness. North of the lake the beds should be the equivalents of the upper strata of the slate quarries, but they are concealed by drift and unexplored. The slate of the quarries on, and of those a little east of Manod-mawr, are certainly the equivalents of the lower part of the quarries a little east of the Manod-bach fault, for they are interstratified with the same ashy beds grown thicker. The Rhiw-bach slate, which dips north at an angle of about 18°, is probably a little higher in the series, but this is uncertain, the adjoining ground being obscured by drift.

Slates have been quarried to a small extent further south in beds, which are the general equivalents of those mentioned above. They lie at and near Llyn-y-drum, where, as already explained, they are interstratified with trap sand ashes, the whole dipping north and north-east at comparatively low angles, so that in working them it would sometimes be necessary to remove a "top" of hard rock so heavy and thick, that like the strata under Moel-y-rhudd it would not repay the labour. These details are, however, almost foreign to the general description which is the main object of this Memoir, since each individual case would require a special survey to illustrate all its capabilities.

Since I visited the country quarries have been opened on Moelwyn in beds which are the general equivalents of the old quarries of Cwm Orthin, and I am informed that openings of

good promise have also been made in Cwm Croesor in strata which I believe must be somewhat higher in the series.

In the slate that overlies the Gamallt porphyry, the lower strata are the equivalents of the higher beds of Moelwyn, Cwm Orthin, and of the north end of the slate quarries by the Manod-bach fault, but whether it be that the material has changed, or that difference of strike has altered those peculiarities of cleavage and jointing that favourably affect the Ffestiniog slate, certain it is that no quarries of any importance have been opened between the Gamallt trap and the fault on the east that runs from Caregog to Ffynnon Eiddew. The same holds true of all the equivalent strata that rest on the ash from the Machno fault, near Pen-y-fedw,* to Mynydd Nodol and Arenig. Indeed, all along the Arenig and Y-Graig range the superincumbent Llandeilo beds are soft black shale rather than slate; and though here and there openings have been made in the corresponding rocks immediately east of the Arans, and from thence along the strike to Mynydd Ceiswyn,† no important slate quarries have been worked in that area.

CHAPTER XIII.

The Caradoc or Bala Beds South of Cader Idris, and between Dinas Mowddwy and Bala Lake.

General Description.—With the formation of the highest porphyries and ashes of Merionethshire there closed a period of volcanic activity in the area described in previous chapters. This was apparently succeeded by a long time of repose, during which a thick series of slaty beds were deposited above the porphyries of the Arans and of the two Moelwyns. But long before the close of the deposition of the Bala beds, the volcanic energy was renewed in part of the same area. I shall now describe this part of the series lying in the country between Dinas Mowddwy, Caernarvon Bay, and Conway, beginning my description with the ground near Dinas Mowddwy, and following the Bala beds, by Bala, Llangwm, and Yspytty Evan, to Penmachno. From thence, I shall resume the account of the mountains north of Moelwyn, and afterwards explain the structure of the large tract of Silurian and Cambrian country that lies between Penmachno, Tremadoc, and the Menai Straits.

Bala Beds, Cader Idris, Aberdovey, &c.—Between Cader Idris and the river Dyfi the country has been described by Mr. Selwyn,

* One mile and a half S.S.W. of Penmachno.
† Three miles and a half south-east of Dolgelli.

as consisting of "dark blue and grey arenaceous and argillaceous "slates, with thin beds of very fine grained grey and brown "banded sandstones." Both are occasionally flaggy, especially between the Dyfi and the high range of hills that strikes north-east from Pen-y-graien to Garnedd-wen. This range is chiefly occupied by blue sandy slate interstratified with thin grits, and occasional thicker beds of quartzose sandstone and conglomerate, partly composed of felspathic grains. These generally dip south-east at high angles, and bands of good roofing slates, and flags occur on their south-east flanks, largely quarried at Corys. The whole country being much contorted, it is not unlikely that the sandy beds that form the hills around Pant-y-carneddau, on the road from Machynlleth to Towyn, may be the general representatives of the above-mentioned sandstones. In spite of cleavage a contortion still more intense is evident in the rocks exposed along the shore between Machynlleth and Towyn, where they principally consist of grey and light-blue arenaceous and slaty beds, similar in structure to most of the rocks that lie between the Dyfi and Plymlumon. Their strike is south-westerly, and the cleavage more or less coincides with it, generally dipping south-easterly from 80° to 85°, though it is occasionally vertical. The great Bala fault runs through this district from Llyn-trigraienyn, by Tal-y-llyn, down the long straight valley to Morfa-Towyn. Its amount is unknown, but, judging by the strike of the rocks, it probably decreases near Tal-y-llyn, and again increases towards Towyn, for the S.S.W. strike beyond Afon Dysynni, apparently, under the alluvium, brings the Lingula flags against the Bala beds, which near Towyn strike W.S.W.

Between Aberdovey and Towyn fossils are said to have been found, but they are certainly scarce, for, in spite of diligent search, none have been discovered anywhere else between Aberdovey and the Bala limestone beyond Dinas Mowddwy, although, judging by strike, position, and an occasional slightly calcareous appearance, it is not unlikely that some of the rocks of the sandy beds of Pen-y-graien and Garnedd-wen may be on the general parallel of the Bala limestone.

Wales South of the Dyfi.—Bala beds, with the Lower Llandovery rocks, form the greater part of the Silurian rocks of Wales south of the river Dyfi, occupying the west of Montgomeryshire and Radnorshire, the whole of Cardiganshire, and by far the greater part of the counties of Caermarthen and Pembroke. A fault probably runs up the course of the Dyfi, the strike of the strata on its opposite banks being generally discordant. The Bala and Lower Llandovery rocks are spread over this great area of more than 2,000 square miles by innumerable undulations of the same strata, but north of Cemaes the very rocks that, south of Cader Idris, form a half of South Wales are all comprised in the strip of hilly ground that lies between the Denbighshire flagstones and the Arans. They are there less contorted, and dip more steadily eastward, and nearly 14,000 feet of strata are

squeezed into a breadth of about 6 miles* (fig. 8 and Pl. 28, No. 3).

Dinas Mowddwy.—Near Dinas Mowddwy fossils were found on Moel Benddu, Moel Dinas, Blaen-y-pennant, and further north at Pum-rhyd, in black earthy slates. They consist of ordinary Caradoc species *Trinucleus concentricus, Asaphus Powisii, Berychia complicata,* together with *Orthis vespertilio, O. Actoniæ, Strophomena expansa, Leptæna sericea,* and several other trilobites, corals, and shells, much distorted by cleavage.†

Bala Limestone.—"Immediately to the north of Dinas Mowddwy a set of beds begins to appear near the middle of the dark earthy slates, rather different in general lithological character from the beds to the south-west. These beds have been long known as the Bala beds, and are now proved to be the equivalents of the Caradoc sandstone of Shropshire.

"In the middle of the Dyfi, half a mile north-east of Dinas Mowddwy, may be seen a small band of dark limestone, about 3 feet in thickness. This is the first appearance of the Bala limestone."

This limestone runs in the middle of the series, first in a long straight line with a north-east strike, and afterwards near Bala broken and repeated by faults.

"The Bala beds spread over a broader area and become highly fossiliferous as they go northwards, and in the neighbourhood of Bala Lake assume the following characters.

"The principal mass of them is a very fine-grained arenaceous slate rock, of a light grey colour. This commonly contains very minute flakes of mica, which, as well as the grains of other minerals, are so small as rarely to be distinguished by the naked eye. Some of the beds are very hard and compact, with a conchoidal fracture, others are affected by a slaty cleavage, but this is commonly irregular, and not well pronounced, and they never afford anything like good roofing slate.

"About the middle of this set of beds occurs the band of limestone. This has a well-marked and peculiar lithological character, which it preserves almost throughout its entire course. Some parts of this limestone differ but little from the sandy slate rock in which it lies, except in being calcareous, but its more well-marked portions contain bands from 1 to 6 inches thick, of a nodular or concretionary character, the centre of the nodules being crystalline grey argillaceous limestone. These nodules so blend one into the other as on the weathered surfaces to form rough projecting bands or mouldings standing out from the face of the rock. The space between each band is commonly about the same width as that of the bands themselves. The lowest part of the limestone frequently contains large nodules or concretionary masses of a black crystalline limestone, which sometimes forms a regular bed, about 3 feet in thickness, with veins of white spar. The thickness of the whole calcareous mass commonly does not exceed 20 feet, and rarely even attains to that magnitude. Besides the fossils of this limestone, which will be named hereafter, it is very frequently characterized by the occurrence of small black nodules, of the size of a walnut, that often remind one of coprolites. Some

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* The area referred to is shown in Map pl. 27, or in the one-inch maps, sheets 40, 41, 42, N.W., 56, 57, 50, 60, and 74; Horizontal section, Sheets No. 26, lines 2, 3, and 4, and 29. Line 3 shows the structure of the contorted country south of Cader Idris, and of the 6 miles alluded to east of the Arans.

† What follows in inverted commas as far as page 94, has been contributed by Mr. Jukes, except in one or two cases expressly mentioned. Mr. Jukes surveyed the chief part of the Bala beds, between Dinas Mowddwy and Penmachno.

of these were analyzed by Dr. Playfair and found to contain a large proportion of phosphate of lime.

"About 1,200 or 1,400 feet below the limestone are some beds of a peculiar lithological character called "ash" in this Memoir.* These ash beds are of three varieties,—the flaky, the brecciated, and the crystalline. The first is the most characteristic, in which the granular materials of which the rock is more or less composed are coated, and separated by flakes of a smooth fine texture, often resembling chlorite, which on a fresh surface of the rock give a soapy feel when rubbed in one direction. These flakes lie pretty nearly in one plane, but that is very often not parallel to the plane of stratification, but perhaps most commonly oblique, or even at right angles to it. The crystalline varieties differ from the flaky chiefly in the granular portions, which consist in a great measure of distinct shining crystals of felspar or other minerals, with their angles scarcely at all worn, and their facets quite bright. They are with difficulty separable from the matrix. The brecciated ash beds are, as their name denotes, made up of worn but still angular fragments of rock, varying from mere grains to pieces half an inch in diameter, compactly imbedded in a fine-grained matrix of much the same mineral character as the fragments themselves. Many of these fragments are pieces of felspathic trap, the crystals of felspar being easily recognized in them. All these varieties pass into each other or alternate in the same beds, being separated here rather for convenience of description than for any real distinction between them. One remarkable circumstance is, that these ash beds are almost without exception sufficiently calcareous to effervesce on any new surface with very dilute muriatic acid, a quality which is never perceptible in the grits or slate rocks immediately above or below them.

"The external appearance of the ash beds, as seen where they crop out on a hill side, at once distinguishes them from the ordinary sandy slate rock of the rest of the Bala beds. A bed of ash only 2 or 3 feet thick can be traced by its more massive appearance, and by the rounded form and greater distinctness of its blocks. When its thickness reaches to 10 or 15 feet it often forms a feature that can be discerned at the distance of half a mile, and its aspect very frequently resembles that of protuberant trap dyke. The lamination of a thick bed of ash is rarely perceptible, the stratification being determinable only by its upper and lower surfaces. Sometimes, however, it contains bands of a different texture from the rest of the mass, which then coincide with the general planes of bedding, and show its strictly stratified character. From the singularly broken and disturbed state of the country occupied by these beds it is rather difficult to say with perfect accuracy how many ash beds the Bala rocks contain in the immediate vicinity of Bala. In part of the district, at all events, there appear to be certainly two having the same mineral character. In one or two places also an ash bed of a rather different character from the others, and generally more crystalline, appears immediately below the limestone.

"In order to understand the lie of the Bala beds it will be best to describe in detail the range of the Bala limestone from its commencement in the bed of the Dyfi, near the flannel factory of Aber Cowarch, a little north of Dinas Mowddwy. From this spot it runs by Pen-y-bryn, Bryn Sion, Bwlch-y-Sygyn, and at the head of the vallies of Cwm Escyll, and Cwm Dinewid.† It is also seen occasionally peering from under the bogs at the tops of the intermediate hills, and is admirably shown in the valley of Blaen-y-pennant, which it crosses one-third of a mile west of the turnpike road, and it may be traced thence at intervals across the moors to the west side of Craig-yr-ogof.

"It does not strictly preserve the whole of its characters throughout this stretch of 10 miles, as it in some places loses the black crystalline masses near its base, and in others (Blaen-y-pennant, for instance) the slate, both above and below it, for 10 or 20 feet, becomes slightly calcareous, and in places almost as much so as the limestone itself. It is probable, also, that occasionally the

* "The ash beds were well known to the people of the country, by whom they are "called 'cerrig llwydion,' 'the grey or brown stone.' A house on the west side of "Bala Lake is thus named from standing on a bed of it."

† Cwm Dinewid is called Afon Penrhyd in the Ordnance map.

calcareous matter almost entirely disappears, as the limestone is not to be seen at one or two spots, where from the strike of the rocks on each side it ought to appear. On the east side of Craig-yr-ogof, one of the places thus poorly provided with lime is actually seen, the beds having the external appearance of the limestone, and all its banded character, but only effervescing very feebly with acids.*

"A little distance to the west of this spot, coming out just from beneath the limestone, is a well characterized ash bed, the first appearance of that kind of rock as we come up from the southward. All the usual fossils of the formation are found in the neighbourhood of the line of limestone throughout this tract, and also for some slight distance in the rocks below it, but do not appear to extend far into the rocks above.

"So far the strike of the limestone is remarkably regular, running in a nearly straight line N. 30° or 35° E., parallel to the outline of the traps of Aran on the west, and that of the Tarannon shale and Denbighshire sandstone on the east. Its dip is E. 30° or 35° S., almost always at an angle of 40° or 50°.

"Throughout this extension the beds near the limestone pass both upwards and downwards into fine-grained rotten black slates, which on the one side lie below the Tarannon shale and Lower Llandovery beds, and on the other rest upon the porphyritic rocks of the Arans. Both the upper and lower slates are occasionally affected by some large flexures which, in this part of their course, have not extended into the strike of the limestone.

"Just north of Craig-yr-ogof is a space of about a mile and a half, in which hardly a fragment of rock can be seen near the strike of the limestone, so entirely is the surface covered by thick black bogs and heather. North of this it again suddenly makes its appearance in two places, one about half a mile east by south from the top of Moel-migynau, the other down in Cwm-llysog.† The first-named piece cannot be traced many yards; the latter however runs down the brook with many small undulations to a fence and sheepfold, and then strikes up the hill towards the north of the word "Murddyn" in the map, where it is is lost under the peat. It reappears south of Maes-meillion, and can be traced thence continuously up to some large limestone quarries and old kilns on the hill side south of Bryn Bedwog. It is here curiously contorted and twisted about in various directions, forming one or two small arches and domes, but none of the pieces run far, and no limestone çan be found in the brook beneath; it is evidently cut off by a fault. About half a mile to the north-east, however, just outside the fences on the north of the hill called Moel-fryn the limestone is again found dipping first south-west, then south-east, and then north-east, and a good deal broken and contorted. It disappears again under a bog, but may be detected in the brooks between Bryn-melin and Yspyddadog, whence it can be traced to the quarries of Y-Gelli-grin. It is here again bent and broken, dipping in one place north by east at 15°, then south at 45°, but having a general inclination about E.S.E. Both at the quarries on the north end of Moel-fryn and at Y-Gelli-grin there is a crystalline, calcareous, and fossiliferous ash bed below the limestone, separated from it by about 30 or 40 feet of other beds, and down the road towards the house of Y-Gelli-grin there is a well-marked fault running a little west of north, and dropping the beds to the east about 30 or 40 feet perpendicularly, so as to bring the limestone to the east of the fault exactly into the line of the ash bed to the west of it. As a bank and fence separate the two pieces, this circumstance would be likely to mislead a hasty observer, both as to the number of the beds and their character. These beds cannot be traced below the house, but on the opposite side of the brook they may be seen running north up the hill of Bryn-cut. On the north side of this hill, however, they are abruptly cut off by a fault, and also contorted, as the ash bed is suddenly deflected and made to strike at right angles to it former course, and abut against the limestone, which just beyond suddenly ends. Both beds are again seen about one-third of a mile to the northward between Y-Garnedd and the brook, but very much broken, striking in much confusion in different directions, and in the last piece of limestone neither strike, dip, nor regular

* *See* Section, Sheets No. 29, line 3, and No. 37, line 4.
† About 3 miles S.E. of the southern end of Bala Lake.

bedding can be discerned. On the opposite side of the road the same confusion is observable in the common Bala beds which lie at all angles and positions, and the beds below the limestone are apparently brought into contact with those above it.

"Returning now to the southward to the neighbourhood of Moel Migynau besides the detached piece of limestone to the east of that hill, there is another to the north of it, near a place called Llechwedd-ddu. There is here a small quarry in which the beds of limestone are bent into the sharpest possible angles, but no regular strike or dip is shown. Similar quarries occur at the same level on the opposite side of the glen near Murddyn Marad, but to the north-westward of these there is a regular line of limestone shown on the hill side about half a mile in length, and lying quite undisturbed and nearly horizontal. This ends very abruptly to the north, being apparently cut off by a fault running nearly east and west, on the opposite side of which the dip is south at 30°, or nearly at right angles to its former direction.

"The limestone is next seen much contorted in the bed of the brook north of Caer Hafotty. To the north or this a very regular oval outlier, forming a small basin-shaped piece, supporting a patch of slate in its centre, lies on the hill side, and north of that again are two other detached pieces, one about 100 and the other about 50 yards long, both very regular and dipping at a slight angle to the south. Both those pieces are evidently cut off by faults running nearly north and south.

"The occurrence of this line of detached pieces from half a mile to a mile west of the limestone before described is due to the effect of an anticlinal curve, the axis of which runs nearly north and south between the two, tilts the beds over at a sharp angle to the west, and repeats the limestone in that direction. This westerly dip, however, is not continued far, the beds very shortly flattening, and then rising to the west so as to form a synclinal line parallel to the anticlinal. Before, however, this synclinal curve is fully carried out some considerable faults occur, running about north and south, and throwing up the beds on their west side. The extension of the limestone is therefore cut off abruptly in that direction. Moreover, as no large faults can exist without cross fractures or curvatures, the portions of limestone are no doubt separated by these as well as by the convolutions of the beds on which they rest."

Beds below the Bala Limestone.—"I shall now trace the rocks below the beds associated with the limestone. I have said that the Bala beds pass downwards into black slates. As they range northwards these beds become affected more and more by flexures and faults, and spread over a greater extent of country than they occupy between Bwlch-y-groes and Dinas Mowddwy. Owing partly to the quantity of drift matter lying on the hill sides south of Bala Lake, partly to the grass and turf with which the rocks are concealed, and partly to there being no peculiar beds capable of being traced in that district, it is impossible to give any other than this general account of it. There is, indeed, an ash bed just under the limestone of Craig-yr-ogof, and another in the brook behind Tai-yn-y-nant, but neither can be traced for more than a few yards. On the east flank of the hill, however, called Cefn-gwyn, south of Llangower, and in the valley between it and the limestone, the ash begins to make its appearance in greater force, and from this point to the northward, ash beds make a permanent and important feature in the Bala group. There is, I believe, on the east side of Bala Lake only one ash bed; this, at its very commencement north-west of Y-Fedw, is broken through apparently by the same fault that cuts off the limestone before mentioned as running north-west of Mwraddyn Marod. Other dislocations are also apparent in it, but beyond these, from the bed of the brook a little to the northward, it runs in nearly a straight line to the east of Glyn-mawr and Glyn-bach up to the east end of the wood at the back of Pant-yr-onnen. This line is nearly parallel to that of the detached pieces of limestone before described, but the two gradually approach each other towards the north, till on the brow of the hill looking down on Bala Lake the ends of the ash and the limestone are scarce 50 yards apart. A fault running about north by west occurs between the two, and, by following that line, the extension of the ash bed is discovered on the east side of it, by the road between the words "Bryn" and "Hynod" on the map. Just in the same way, however, as the limestone above it, so is this piece of ash shortly cut off

by another north and south fault, also a downthrow on the east, and its extension is found a quarter of a mile to the north in the wood of Tyn-y-twll. Here the ash bed has come within the range of the anticlinal line before spoken of, and is affected by it to some extent, its outcrop running south-east and then north-east, but broken in one or two places by small cross fractures. As the ground hereabouts slopes sharply to the north, the bend in the outcrop of the beds makes but little feature in the map, still there is an indentation in the crop of the ash bed answering to the deep east and south flexure in that of the limestone. From this spot the ash bed runs to the N.N.E., frequently broken by faults, throwing it from 50 yards to a quarter of a mile on one side or other of its course, but being generally parallel to the broken line of the limestone to the eastward. One of these faults at least can be traced through both beds, as, if we join the ends of the ash beds west and north of Cornelau by a straight line and produce it to the south, it passes close under the broken limestone south of Bryn-Bedwog, which we saw before must be cut off by a fault, as none of it is found in the brook below. It would be tedious to enter further into details, neither is the scale of the Ordnance map sufficiently large to show them, or even to make all of them out in the field except in a general way. The reader, indeed, must be advised that the faults marked in the map are rather a selection to show their general nature than a true representation of those which could be shown to exist did the scale of the map allow of it."*

Before proceeding further I shall describe in a little more detail the beds below and above the Bala limestone.

From Cefn-coch, near Mallwyd, to the Bala fault, on the river Dee, from 2 to 3 miles east of Bala, these rocks pursue for 16 miles a course as straight and regular as the limestone itself does between Dinas Mowddwy and Craig-yr-ogof. Their average strike is about N. 20° E., and their dip E. 20° S., from 40° to 60°. The angle rarely reaches 70°, and is occasionally lower than 40°, especially in the ground about Craig-ddu and Moel-fryn, west of Hirnant, where it flattens, and undulates eastward at angles of from 5° to 20°. The rock here principally consists of a fine-grained blue slate, sometimes arenaceous, and sparingly interstratified with beds of thin grit. East of Aran Mowddwy these are overlaid by about 500 feet of grey felspathic grits and thin beds of interstratified slate, that form the Lower Llandovery beds. These in turn are overlaid by the Tarannon shale and Denbighshire sandstones.†

Hirnant Limestone, &c.—Not one ashy bed occurs in this area above the Bala limestone, but a thin band of the Hirnant limestone of Sedgwick is found on the brow of the rocks called Trum-y-gwrageda, where a footpath crosses that ridge, and the same rock occurs at another spot in the Hirnant valley, in a small quarry about a third of a mile west of Cwm-y-aethnen. It is fossiliferous, black, and pisolitic, the concretions being about the size of small grains of barley, When fractured they are both concentric and radiated, and in the centre there are frequently small rhomboidal crystals of carbonate of lime. The concretions are

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* "The small scale of the map had two inconveniences :—It seldom, by the features marked on it, enabled me to fix myself with sufficient accuracy when bearings or angular measurements were difficult to obtain, and it often rendered those measurements useless when obtained by not enabling me to protract them. Moreover, the portion of the surface occupied by the limestone and ash beds, as also the width of the faults, the size of the arrows for dip, &c., must necessarily be enormously distorted in order to render them discernible. The space actually occupied by the outcrop of the limestone was rarely more than 4 or 5 yards, while that taken by its representation in the map is never under 50, and very often equals 100. Were it drawn on a strictly natural scale it would be barely visible."

† Though foreign to the present description, it may be well here to state that these rocks are well shown on the turnpike road, and in the river bed east of Mallwyd, where they undulate with many contortions across 8 miles of country, and finally dip under the Wenlock shale near Garthbibio.

cemented in a crystalline base. "The same limestone appears on "two other spots on the west side of the hill behind Aber "Hirnant, near the road going up to Maes-hir, but it is less "developed, and consist principally of calcareous nodules, which "in one place were quarried for lime. None of these patches are "connected with each other, nor could I find or hear of any "other spots where they occur, except at the Pass of Bwlch-y-"groes above Llan-y-Mowddwy, where Professor Sedgwick "found loose fragments of limestone in the same line of strike." The rock therefore scarcely deserves the name of a special limestone, although no doubt the pieces are nearly, if not exactly, on the same parallel with that of Hirnant.

Fossils.—The beds beneath the Bala limestone are rich in fossils, and east of Aran Benllyn, at Tyn-y-fron and Tai-yn-y-nant, yielded the following species:—

Nebulipora favulosa, N. lens, Cythere umbonata, Homalonotus bisulcatus, Beyrichia complicata, Orthis alternata, O. flabellum, O. elegantula, and *Leptæna sericea.*

In the neighbourhood of Bala lake the rocks are on the whole more sandy than slaty, and great surfaces of slab-like beds are in some of the quarries entirely covered with casts of *Orthis elegantula, Leptæna sericea,* and the rings of *Encrinite* stems all belonging to a single species, *Glyptocrinus? basalis.* There are also in many of the beds large tubes of annelides lying, some in horizontal and others in vertical positions (*see* Pl. 14). Star fish (*Palæaster*) are occasionally found, and of trilobites *Trinucleus concentricus* and *Homalonotus bisulcatus* are the most prevalent. Corals are scarce, the varieties of *Stenopora* being almost the only species found. *Cystideæ,* though abundant in the limestone, have never been found in the beds above or below.

In the Bala limestone itself fossils become exceedingly numerous, and it is in many places chiefly composed of comminuted fragments of shells, corals, and trilobites, intermingled with more perfect specimens. A good example of this kind of structure occurs at Murddyn-marad, where there is also much false bedding in the associated shales, and ripple or current markings in the rocks below. The whole has a shallow-water aspect. The following species are among the most characteristic fossils of the limestone east of Bala lake:—

Corals:—*Nebulipora favulosa, Stenopora fibrosa.* Encrinites. Trilobites:—*Calymene brevicapitata* and *C. Blumenbachii? Asaphus Powisii, Lichas laxatus, Trinucleus concentricus, Phacops apiculatus, Illænus Bowmanni, Cheirurus bimucronatus, Homalonotus clavifrons, H. bisulcatus,* and *Beyrichia complicata.* Bivalve and Univalve Shells:—*Orthis vespertilio, O. calligramma, O. elegantula* and *O. testudinaria, O. Actoniæ, O. flabellulum* and *O. biforata, Strophomena grandis, S. tenuistriata, S. expansa, S. depressa, Leptæna sericea,* and *Lingula ovata, Ctenodonta varicosa, Modiolopsis* and *Orthonota,* and *Cyclonema crebristria, Murchisonia simplex,* and *Bellerophonon bilobatus;* also *Orthoceratites.*

Immediately above the Bala limestone, fossils are numerous, being usually of the same species as those in the limestone itself.

Fossils of Hirnant.—The fossils found in the Hirnant limestone consist of the following species :—

Orthis Hirnantensis, O. sagittifera, O. turgida, O. biforata (and varieties), *O. elegantula, O. testudinaria, Arca Edmondiifarmis, Modiolopsis modiolaris.* With the exceptions of two first named, all of these are Bala species.

In the beds of the Bala series, immediately above and below the Hirnant limestone, fossils are exceedingly scarce, and the specimens are usually very imperfect.

Thickness of the Bala Beds.

It will be recollected that the igneous rocks, between Aran Mowddwy and Llanywchllyn, the felstone porphyry thins from 2,300 feet to 1,100 feet, and the ash from 3,200 to about 1,050 feet. The same kind of diminution may be remarked in the Bala beds.

According to the measurement of Mr. Selwyn, the thickness of the rocks between the Aran trap and the limestone is 5,500 feet, and that between the limestone and the Tarannon shale is about 5,000 feet. This is immediately east of Aran Mowddwy (plate 28, fig. 3). According to Mr. Jukes's measurement between Moel-ddu, Moel Migynau, and Hirnant there is a thickness of only 4,000 feet between the trap and the limestone, and 3,000 between the limestone and the Tarannon shale (fig. 8). Assuming these measurements to be approximately correct, it is evident that a great change in the thickness of these strata takes place in the course of 4 miles. Whatever may have given rise to it, the fact is significant. The whole thins out towards the north, and it is remarkable that the coarseness of the beds, and the increase of fossils in the Bala beds, bear a relation to this diminution in thickness, indicating perhaps a nearer approach to the shore of the period.

CHAPTER XIV.

THE BALA BEDS, FROM BALA TO PENMACHNO.

General Description. Bala Limestone.—I have now described the range of the rocks from the southward up to Bala Lake and the valley of the Dee. The great Bala fault, the south-western prolongation of which has been previously described, runs through the lake, and, accordingly, a great part of the beds of the south and east sides of the lake are repeated on the west and north of it.

Between Bala and Cerrig-y-Druidion we enter upon troubled ground, in that north-eastern part of the Merionethshire anticlinal which is marked by the sharp curvature of all the strata, in the ground between the Arenigs and Derwen.* When the geologist

* Derwen lies about 12 miles N.N.E. of Bala.

first attacks the country, he is everywhere met by conflicting dips, strikes, and unexpected patches of limestone and ash scattered hither and thither in apparently inextricable confusion, conveying the impression that not one or two, but many short beds of limestone and ashes are interstratified with the other rocks; and it was only by the expenditure of much labour and skill, that Mr. Jukes was able to dissect the main features of this intricate puzzle, and prove that all the limestones are parts of one and the same bed, and that there are only two lines of ashy strata.

"It has been clearly ascertained that the Bala limestone and the limestone of Rhiwlas are the same bed; that the line of the Bala limestone previously described, after ending at Y-Garnedd, is taken up at Rhiwlas, 2 miles to the W.N.W., or in a direction at right angles to its previous general strike. If we supposed this dislocation to be the effect of one fault, and the mean dip of the beds to be 25°, it would involve a perpendicular downcast to the north-west of about 5,000 feet. Regarding this result as the effect of one principal fault, we have by no means the whole amount of fracture and dislocation that has affected the country we are now entering on. Several other faults of great magnitude can be traced in it, as well as numerous and strong flexures in the dip and strike of the rocks, producing a most singularly contorted and broken district. In describing this I will endeavour to condense the local details, and give, in as few words as I can, a sketch of that structure which required some months of hard labour to make out.

"In the first place, then, the rocks on the north-west of Bala lake, between the mouth of the Llafar and the Tryweryn, are precisely the same group of beds as those on the south-east side. They are composed of the same grey arenaceous slate rock, resting on the same black slates, which undulate with several flexures over the ground to the westward, until they finally crop out, resting on the traps of the Arenigs, precisely as they do to the southward on those of the Arans. The grey grits on both sides of the lake contain ash beds of precisely similar character. As we trace them to the north we find, as soon as the ground admits of it, that the limestone comes in above the upper ash bed at the same distance as it preserved on the east of the lake.

"The frequent repetition of the ash and limestone, always bearing the same relation of position to each other, and having the same strata below, between, and above them, establish their identity. These characters are too constant to be accounted for by accidental resemblances in different strata, while, unless they are supposed to be identical, the structure of the country becomes altogether unintelligible. By a fortunate chance a quarry was opened in the limestone of Rhiwlas, a mile north of Bala, while the district was being surveyed. Professor E. Forbes was himself present, and from this quarry a number of fossils were procured that have hitherto been found nowhere else."

Rhiwlas, &c.—The Bala limestone at and near Rhiwlas being unusually rich in fossils, I give a fuller list of them than usual,

copied from the Survey List book. Those that are not found, or are very rare, south and south-east of Bala Lake, are marked with an asterisk.

CORALS.

Stenopora fibrosa.
Chætetes petropolitana.

CRINOIDEA.

*Pleurocystites.**
*Hemicosmites.**
*H. rugatus.**
*Sphæronites munitus.**
*S. Litchi.**
S. .*
S. .
S. .
*S. punctatus.**
*S. pyriformis.**
Echinosphærites Davisii.
*E. granatum.**
Roots and stumps of *Encrinites*, some of them pentagonal, *Annelidæ* and *Serpulæ*.

BRACHIOPODA.

*Leptæna tenuicincta.**
*L. quinquecostata.**
L. sericea.
Strophomena depressa.
S. expansa.
Orthis Actoniæ.
O. elegantula.
O. simplex.
O. biforata, and others.
Lingula.
L. ovata.
*Rhynchonella bidentata.**

LAMELLIBRANCHIATA.

Modiolopsis or *Mytilus.*
Orthonota.
Ctenodonta, varicosa.

TRILOBITES.

*Illænus Davisii.**
*Phacops Brogniarti ?**
Cheirurus bimucronatus.
C. clavifrons.
*Encrinurus sexcostatus.**
*Cybele rugosa.**
Trinucleus seticornis.
T. concentricus.
*Ampyx tumidus.**
Acidaspis .*
*Remopleurides Colbii.**
*R. longispina.**
*R. radians.**
Lichas laxatus.
*Agnostus trinodus.**
Asaphus Powisii.
Beyrichia, very numerous.

GASTEROPODA.

*Holopella conica.**
*H. lymnæoides.**
*H. exserta.**
*H. carinata.**
Murchisonia .*
Raphistoma. .*
R. .*
Bellerophon bilobatus.
B. nodosus.

CEPHALOPODA.

Orthoceras vagans,* and 5 or 6 others unnamed.*
Lituites cornu-arietes, and 2 others.
Cyrtoceras, several species.*

Bala Beds, Tarannon Shale, and Denbighshire Sandstone.

"Nearly directly north of the town of Bala, limestone is found at four places, Rhiwlas, Llwyn-y-ci, between Penmaen-isaf and Penmaen-gannol, and at Eglwys-Anne, places arranged on a line running about N. ½ E. and S. ½ W., and from one-third of a mile to a mile apart. At each place the limestone dips nearly south at from 10° to 30°; a person, therefore, merely walking from one to the other would at once set them down as four separate beds of limestone, and assign a very great thickness to the whole group containing them. It is found, however, that neither of the three first-named pieces of limestone can be traced along the strike for more than about 200 or 300 yards. They end abruptly each way. In each case, also, at almost precisely the same distance to the north of the limestone, namely, about half a mile, a piece of ash is found, likewise ending abruptly in both directions, likewise dipping to the south, and in all respects a counterpart to the limestone above it as far as the nature and slope of the ground will permit. Moreover, if we join the ends of each piece of limestone and ash by straight lines, those lines are very nearly parallel to each other, and if we produce them they touch the end of the next piece of ash or limestone below or above, as the case may be. In other words, these lines are faults, each of which is a downthrow to the north-east, and the portions of [redacted]

persistent portions of the same beds. We arrive at one of these larger portions at Eglwys Anne, whence the limestone may be followed continuously in a curved line round the north end of Moel Emoel, and down the valley on the east towards Bwlch-y-Tyno, and then along a more sharply curved and broken line to Creigiau-isaf. Half a mile to the north of the limestone a line of ash follows the same outline in all its curves. They both end in the same manner at a line running nearly north and south on the east side of Garw-fynnydd, and small detached fragments of both are again found dotting the country to the north-east along a probable line of fault, which runs thence to the south-west, and in that direction cuts off the Denbighshire sandstones near Llandderfel. There is thus immediately to the northward of Bala a broken trough, open to the south, the apex of which is at Pen-bwlch-gwyn, its western side being formed of the broken pieces before described, and its eastern side being formed of limestone and sandy slate, dipping west as far as Creigiau-uchaf. To the south of that point, however, or about Rhos-dawell and Moel-dryll,* neither limestone nor ash are to be found, the beds being thick sandy slates, with current or ripple mark often visible on their surfaces. They form altogether a bulky mass of very great thickness, dipping west at a high angle, and often absolutely perpendicular. I conclude the proper place of those Bala beds is somewhere above the limestone, and believe that a fault running about W.N.W. and E.S.E., runs somewhere at the northern end of Rhos-dawell and between it and the limestone.†

"Returning to the north end of the trough before described, the line of the Llandderfel fault would pass, if produced, just north of the ash of Pen-y-bwlch-gwyn. This fault seems to branch first about a mile north-west of Llandderfel, and again on the southern slope of Moel-y-Darren, the intermediate pieces of rock being thrown down to the northward. We accordingly find the evidence of its continuance thus far in a recurrence of the ash bed, with nearly the same contour as on the ground to the northward of it, but modified by the shape of the country. From each end of this piece of ash also smaller fragments are let in between cross fractures. Thus far, or from Bala to Y-Gesail, the dip of the rocks along the centre or axis of this rudely trough-shaped piece of country has been uniformly south. On Y-Gesail, however, it flattens to the north, and for about half a mile the beds are as nearly as possible horizontal, and then begin to dip gently to the north. From this dip it results that a considerable and very conspicuous outlier of the ash is found on the summit of Craig-y-llwynog, and on the opposite side of the ealley, or about Gelli-oedd and Llechwedd-fign, it dips under the country to the north.

"We have in this description the appearance of a broad anticlinal curve, the centre of which is Y-Gesail, from which the beds dip north and south respectively; this is true so far, but the anticlinal line is a very short one, the beds from under it, while they dip north and south, rising pretty rapidly towards the east and west respectively, and thus making a mere saddle rather than a long ridge. The anticlinal curve is in fact a part of the great Merioneth anticlinal, the minor fractures and contortions being due to mere local disturbances."

"To see this more clearly, let us shift our point of view. The beds of ash and limestone of Pen-y-bwlch-gwyn and Moel Emoel, after striking for some distance to the north-east, and being shattered by the Llandderfel fault, recover something of their old strike on the north-east side of it, and run north-east for some distance, with a pretty high dip to the south-east. They are, however, much broken by faults, and the limestone has especially suffered, since it only makes one poor appearance about Llwyn-onn, and is never afterwards seen till we reach Pont-y-glyn-diffwys, on the Holyhead road. It is probable, however, that its disappearance is not wholly due to its being concealed by faults, but in part, perhaps, to its thinning out or parting

* From a mile to two miles north and north-east of Bala.

† The great faults which on the western side of the trough run about north by west and south by east must necessarily have one cross fracture or more somewhere; it is possible the fault running across the northern end of Rhos-dawell may serve this purpose.

with its calcareous matter and fossils, so as to be no longer distinguishable. The principal ash bed below it runs on for some distance, and is very well shown round the north end of Pen-y-cerrig-serth and in the valley to the north-east, when it disappears, or at least cannot be traced at the surface. Another ash bed, however, which comes out at a still lower level, and which is of a lighter colour and more flaky character, can be traced on down to Llwyn-Saint on the north-east, and in the other direction is found to form a broken curved line by Ty-newydd, the top of Cwm-da, Y-foel-goch, Fridd-gwan, and Hendre Garth-meilio. It thus partly surrounds the village of Llangwm, viz., on the south-east, south, and west sides, and at every place dips from that village as a central point, passing under the upper ash, which equally surrounds the village at a greater distance. Now the outcrops of these two ash beds keep at a considerable distance from each other in the space described, except at one point just north of Pen-y-cerrig-serth; it might be imagined, therefore, there was a great thickness of rock between them. I believe, however, this appearance is due to dislocations and the nature of the ground. This is rendered probable, because on the north-east of Llangwm, across the Holyhead road, two ash beds occur on the sides of the steep cliffs, with no great thickness between them. These ash beds are likewise much broken by faults, which rather, however, dislocate and disturb the dip of the beds than produce any great amount of upthrow or downcast, and render it difficult to say what is the general strike and dip of the mass, except from that of the beds above and below them. Guided by this, we may say that these ash beds dip at first east or north-east, passing under Cader Dinmael, and then curve over and dip to the north-west, in which direction, after being brought up again once or twice to the surface by faults, they finally disappear just beyond Hendre Arddwy-faen. We now have the village of Llangwm entirely girt by a circle of ash beds, except about 50° of the circumference between W.N.W. and north by west, and find that the dip of the beds is on all sides from Llangwm as a centre. There is nothing in that neighbourhood to account for this circumstance, neither do any beds appear there which could be identified very strictly with the black slates that lie just above the traps of the Arenigs and Mynydd-nodol. The surrounding faults must necessarily traverse this spot also, and probably continually reproduce the same beds at the surface as is their effect elsewhere. The broken dome-shaped form thus assigned to the rocks around Llangwm is merely the result of a local intensity of force, the centre of which is on the axis of the great Merionethshire anticlinal.

"If now we trace the superior rocks, viz., the Tarannon shales and Denbighshire sandstone, we shall find them describing a curved line generally parallel to the curve now assigned to the ash beds. After crossing the river Dee, they run nearly in a straight line N. 35° E. for rather more than 8 miles, or to the banks of the Clwyd between Bettws-gwerful-goch and Derwen. Their dip is from east to south-east, at angles varying from 15° to 50°.

"At a very short distance to the westward of this boundary, however, the mass of the beds are in a very different position, and dip almost invariably south at a very high angle, varying from 40° to 80°. This is most remarkably the case in a band of country about a mile wide and 4 miles long, stretching from the Llandderfel fault to the Holyhead road near Maes-mawr. The position of the rocks here is most anomalous, since they strike towards the ash beds on the west and the Denbighshire sandstone on the east, dipping south at a mean angle of about 60°; yet, as a group, their range is north-east by north, and neither ash beds nor limestone, nor any known lower rocks, can be found among them. I can only explain their structure by supposing a number of faults more or less nearly east and west, causing frequent downthrows to the north, so as to bring in a recurrence of the same beds in that direction. That faults of some sort exist is shown in several places by large masses suddenly striking at right angles to each other, sudden changes of dip at very high angles, and other similar signs of dislocation. When we reach the Holyhead road we at last find the limestone well exposed in the gorge of Glyn-diffwys. It here exhibits its usual characters, having a bed of black crystalline limestone for its base, above which are some banded concretionary beds; these concretions are, however, larger than usual, the beds thicker, and the whole calcareous mass of much greater importance than it generally exhibits. Calcareous matter extends also into the slates above, so that there is a thickness of what may be

called limestone here of about 50 feet. The beds are much broken, dipping at one place south-east and then south-west at 50° and 60°, and finally about south by east at 70°, with which dip they strike along a part of the Holyhead road for nearly half a mile. At the eastern end of the wood under Groes-faen the calcareous beds are suddenly lost, but on the hill-side to the northward above Tyn-y-bryn highly fossiliferous beds with some calcareous concretionary patches are found, dipping to the south-east and east; and, following these along the strike to the northward, a patch of limestone is formed near Hafodty-gader, dipping east at 30°. Immediately north of this spot a rotten arenaceous slate is seen dipping north at 5°, but nearly a mile to the westward the Bala limestone is again found in full force, with all its usual characters, on the top of Cader Dinmael. It is, as usual, both contorted and broken by faults, so that in one place there might be supposed to be two beds of it: its general dip, however, is north at about a mean angle of 10°. To the westward the limestone is suddenly cut off, apparently by a fault, and is never again seen in the neighbourhood in such a form as to be recognized. It will be seen that, notwithstanding its broken condition, a line drawn through the detached pieces of limestone will conform in shape very nearly to the line drawn through the broken ash beds below it.

"In order to mark the upper boundary of the Bala beds I shall here briefly describe the passage of the Tarannon shales and Denbighshire sandstone in their curved course across the great Merionethshire anticlinal.

"The upper beds of the Bala series, after crossing the Holyhead road about Maes-mawr, still retain their high southern dip for some distance but with greater irregularity. About Bettws-gwerful-goch a large mass of them dips regularly to the south-east under the Tarannon shales and Denhighshire sandstone at an angle of 60°. Farther north, however, at Ty-cerrig, the Bala beds are faulted against the overlying strata, but in addition to this there is evidence of a well-marked unconformity, as about Dyfannau the dip of the Bala beds is north at 20°, while the Tarannon shale and Denbighshire sandstone dip nearly east or east by north at about 30°. Where the Denbighshire sandstone crosses the Clwyd, about Tyn-y-coed, some well-marked beds of conglomerate strike directly across the river, dipping east at 45° for half a mile on each side, but further north the beds flatten rapidly, begin to dip more northerly, and the boundary curves to the north-west and about Pont Bod-Reuail, where it again crosses the Clwyd, the general dip is north-east at 20°, with a small local curve to the east, but very shortly a wide and general dip to the north sets in at a not greater angle than 15°. The boundary of the formation then strikes west to the meridian of Cerrig-y-Druidion, and the formation spreads to the northward with several gentle undulations, dipping north and south at about 5°. Throughout this course a narrow band of Tarannon shale separates these sandstones from the upper part of the Bala beds. The upper Bala beds, after suffering one or two sharp flexures to the northward of Bettws-gwerful-goch, causing them to dip in various directions at angles often equalling 70°, likewise acquire gradually a northerly dip; and on Y-Graig-wen, Derwydd, in the bed of the Alwen, and thence to Cerrig-y-Druidion, dip always between north and north-west at angles varying from 5° to 20°, the lesser angle being always the nearer to the boundary of the Upper Silurian rocks.

"We have now traced all the beds, from the lower ash bed to the Denbighshire sandstone, round the sweep of the circle which has Llangwn for its centre, except over a space occupying about 50° of that circle, to the north-west of Llangwm. The two principal defects in the description of the district arise from the absence of the Bala limestone in the space between Llwyn-onn and Pont-y-Glyn-diffwys, and in that between Cader Dinmael and Cerrig-y-Druidion. That absence may be due either to faults, or to the dying out of the beds, or to both conjoined. Quite sufficient evidence remains to show that the strata have been raised into the position of a fractured dome, of which Llangwm is nearly in the centre. When, however, we come to examine the slice of country included in the angle of 50° just mentioned we find ourselves entirely at fault, from the almost total absence of all evidence as to its structure. Neither ash bed nor limestone is to be seen, and over the greater part of the space the boundary of the Denbighshire sandstone is utterly illegible. At a place about a mile and a half north-west of Llangwm, near Hendre-wen, are a

few small quarries, in which the usual fossils of the Bala limestone, and also many specimens of the *Terebatula navicula* were found; there were also a few calcareous nodules. It had, however, no sign of the usual mineral character of that bed. The country around it, and all to the north-west, is so covered with drift that it is rarely a piece of rock *in situ* shows itself. Along the south side of the ridge, running W. ½ S. from Cerrig-y-Druidion, a little rock is seen, commonly an arenaceous flaggy slate of precisely the same lithological character as that to the eastward of Cerrig-y-Druidion, which dips towards the Denbighshire sandstone. The north slope of this ridge is buried under an immense accumulation of drift extending from the flat of Merddwr almost to the summit of the ridge. About a mile north of Cerrig-y-Druidion the Tarannon shale and Denbighshire sandstone boundaries suddenly turn southerly, and the beds dip west at 50°, but very shortly curve back again, and by Ty-tan-y-foel dip north, with slight undulations, at about 5°. With this inclination the boundary sinks into the flat of Glan-y-gors. West by south from this spot the Denbighshire sandstone is seen suddenly to rise up the side of the hill called Garn Brys, and beds of coarse conglomerate, belonging to that formation, are shown very conspicuously on the summit of that hill, dipping N. 30 E. at 25°." On the south this rock is in contact with beds far below the Bala limestone, and it will presently be shown that the disposition of the rocks of this neighbourhood is probably partly to be accounted for by faults.

"In previous descriptions* it has been stated that, when not faulted, the black slates wrap round the upper ashes of the Arenigs and Mynydd Nodol. To the south-east and east they dip under the country which has been already described. On the north-east they dip from the ash of Craig-ddu towards Moel-cwm-maen, on the south flank of which the two Bala ash beds are shown in a less broken condition than usual, the upper one being the equivalent of the ash that underlies the limestone of Moel Emoel, and the lower that of the flaky ash near Llangwm. Farther to the north the ashes are again a good deal fractured, notwithstanding which they turn round conformably to the general outline of the Arenig ash, and dip north from Garnedd-filiast towards Garn Brys and Copa-ceiliawg. On the hill side south of Blaen-y-cwm there is a very thick flaky ash bed of precisely the same character as that which surrounds Llangwm, and which, after dipping west at Hendre Garth-meilio, and passing under Pen-y-Gob, Llechwedd-fign, and Moel-cwm-maen, reappears with an easterly dip about Defeidty-isaf and Cader Benllyn. The upper ash of Moel-cwm-maen can be still more easily identified with a long piece that from near Bwlch-maen-melin runs up to Copa-ceiliawg with a gentle dip to N.N.E. Now, in following the strike of these two pieces of ash, we are in each case led to detached beds of trap, differing in structure from the ashy beds heretofore described. The lower ash strikes directly for a piece of trap seen in the brook of Cwm-gylchedd, and, but for a probable fault, might doubtless be traced into it. The upper ash is lost under bog and earth on one flank of Copa-ceiliawg, but precisely in its strike on the other side of the hill is a bed of hard compact felspathic trap, with a few dispersed crystals. The lower piece of trap in Cwm-gylchedd appears to be much thicker than the lower ash, but is only to be seen in the bed of the torrent. The upper trap is very little thicker or more massive than the upper ash, resembles it exactly in external appearance, and continues in the same strike for half a mile, dipping north at 30° till it reaches the brook running down towards Cerrig-cellgwm-isaf."

Now, on looking at the map, it appears that the Tarannon shales are absent on the east, south, and west of the promontory of Denbighshire sandstone that lies between Pentre Voelas and Garn Brys. Up to this point these shales have been constant, and they again appear in their usual position for a brief space towards Llanrwst, and further north between Llanbedr and Conway, where no fault interferes to cut them off. Further, experience shows that in this neighbourhood, and indeed everywhere in North Wales and Shropshire, they immediately underlie and are conformable with the Wenlock shale, of which the Denbighshire sandstone forms the base, and it is therefore most unlikely that at this point the sandstone should suddenly overlap them. But north-east

* Pp. 48 to 50; 71, 74. 78.

of Garn Brys the Bala beds and Denbighshire sandstone strike directly at each other, and this can only be accounted for by a north-east fault.

"On the south side of Garn Brys the upper ash is but a very small distance removed from the boundary of the Denbighshire sandstone, and as the beds dip at only slight angles there cannot possibly be room for the outcrop of the Bala limestone and superior beds between the two. Either then there is a fault, or the Denbighshire sandstone has crept suddenly and unconformably over the outcrop of the Bala limestone, and covered it from view." The latter supposition is at variance with the behaviour of the rocks of the neighbourhood, and it being certain that the Tarannon shales are also absent, it seems probable that the Denbighshire sandstones are thrown by a north-west fault against a low part of the Bala beds between Garn Brys and Plas-Uchaf, near Yspytty Evan. "On the supposition of unconformity we should probably find the Bala limestone reappearing from under the Denbighshire sandstone somewhere farther on if we followed its boundary. Now in following the brook called Afon Clettwr, a little beyond the bridge of Pont Clettwr, we find some large blocks of Bala limestone almost if not quite in situ, and the Denbighshire sandstone capping the hills above at Ty-newydd. This evidence is rather in favour of the supposition that the Denbighshire sandstone has crept unconformably over the Bala beds. But there must also be some fault or faults to account for the relations of the two between Plas-Uchaf and Pentre Voelas."

The same evidence of conflicting dips and general absence of Tarannon shales (except in one spot, which strengthens the proof) give strong presumptive evidence of a fault which throws down the Denbighshire sandstone on the north-east against the Bala beds between Pentre Voelas and Hendre-wen, near Llanwrst, and also on the east under the alluvium of the Conway between Hendre-wen and the country 2 miles south of Caerhun.

"From the Clettwr the limestone is not traceable in either direction on account of the drift and other superficial covering; but a quarter of a mile south of Yspytty Evan, near Ty-nant, calcareous beds are seen, which strike for the river Conwy, a little above the village. Here the limestone is found in its most characteristic form, and is traceable thence up the hill by Hafod Evan, when it seems to spread on the hill side, and thence turns down again into the Conwy opposite Craig-ddu. It thence again strikes up the hill above Pennant, and is well shown on the moors above the wood, when it appears suddenly to end, dipping east at an angle of 25°.

"Its next appearance is about a mile north of this spot in the brook south of Blaen-eidda-isaf, and then on the hill side above Tyn-y-graig, dipping E.S.E. at 25°. It is traceable thence to a line of quarries which run over some hills north of a moor called Pen-llech. In these it is excellently shown with all its usual characters, and runs down, with some contortions, into a large wood between Penrhyn-uchaf and Dylase-isaf. It is here lost sight of, but is again found on the opposite bank of the Conway, running for about half a mile to the N.N.E. by the house of Berthidion. Between this spot and Llanrwst no trace of it has been found.

"We have previously traced the course of the lower rocks containing the ash beds up to the river Clettwr. I will now briefly describe their further extension.

"In the first place regular ash beds are not met with anywhere round the valley of Yspytty Evan. In their place, however, and about the same distance below the limestone, occasional masses of a very singular rock are found. This has a felspathic base, sometimes hard and compact, at others flaky—in the one case like a trap, in the other like an ash. It is crowded with round concretions varying from the size of a pea to that of a man's fist. In some cases these form a mere nodule of compact rock like the base, but in others they are regular agates with concentric coats and a crystalline nucleus. This rock does not occur in regular beds, but in roundish lumps and bosses, sometimes not more than 10 yards, sometimes as much as 100 in diameter. The bosses do not appear to produce any confusion in the adjacent beds, but appear as contemporaneous as the ash beds. This is farther shown by their occurring always along a certain horizon at a regular distance from the limestone, the line of the two always running parallel in all their curves over the country.

Thus the line passing through these bosses runs along the hills south of Yspytty Evan on the right bank of the Conway, parallel to the limestone, crosses the river about half a mile above Pennant, and then by Blaen-eiddew-uchaf up to Penllech, where it forms the very conspicuous bosses of Carn-y-parc, &c., and thence down to the Conwy at its junction with the Machno. This curved line evidently marks the existence of a rude synical depression, the axis of which runs about N.N.E. in, or parallel to, the valley of the Conway about Yspytty Evan. This depression, however, can only be indicated approximately, for the whole of the country on both sides of this part of the Conway between Pentre Voelas and Dinas House has been violently disturbed, and the rocks now lie in great confusion at all angles and in all positions. Several small anticlinal and synclinal lines can be traced in them running due east and west, with the rocks dipping north or south at 70° and 80°. In several places the beds are perpendicular, striking east and west, while close by the same beds may be seen dipping in various directions at no greater angle than 5° or 6°."

It will be recollected that one or two places were mentioned in the neighbourhood of Bala, where a crystalline ash bed was found about 30 or 40 feet below the limestone. This is represented in the Penmachno district by a very considerable bed of contemporaneous trap, lying just below the limestone on Penllech, and near Berthidion. It is in some places at least 50 or 60 feet thick, but thins out to an ash bed of about 10. It is sometimes nodular or concretionary.

From the junction of the Machno and the Conwy, to which we had brought the nodular ash or trap mentioned before, we may trace it still half a mile or a mile to the north-west, where it forms a large and imposing mass called Bryn-y-ddinas. From this, another series of great bosses and masses of the same rock may be traced to the south-west, along the top of the ridge forming the south-east bank of the Lleder, and thence to Ro-llwyd and Ro-wen, the two highest points between Penmacho and Dolwyddelan. This curved line running along both sides of the valley of the Machno shows it to be occupied by a rude anticlinal arch, the axis of which runs N.N.E. and S.S.W., parallel to the synclinal line of the valley of the Conway near Yspytty Evan. This is corroborated (if need were) by the position of a faulted ash bed, near Penmacho, which represents the lower ash of Cerrig-y-Druidion and Bala, or, at all events, is very near its horizon. It is much broken; but a line joining its detached portions would run from the east side of the Machno, near Bryn-y-grug, through the village, and thence up the valley of Glascwm, forming a smaller and inner curve parallel to the outer and larger one of the nodular trap above, and parallel also to the general outline of the broken curve of the Llyn Conwy and Manod ashes below.

CHAPTER XV.

The Country between the Manods and Moelwyn, Moel Siabod, and Nant Gwynant.

General Description.—The Bala beds have now been described from the neighbourhood of Dinas Mowddwy to the heights between Penmachno and Dolwyddelan. I shall continue this description through the slaty region that lies between Moelwyn, Nant Gwynant, and Moel Siabod, leaving to succeeding chapters the great

mountain range that lies between the Conwy, Traeth-mawr, and the Menai Straits.

North of Moelwyn and the Manods the slaty rocks dip north and north-west, plunging under the felstones and calcareous ashes of Dolwyddelan and of the equivalent traps of the Snowdon region south-east of Llyn Gwynant and Llyn-y-ddinas. The slates are associated with numerous lines of hornblendic greenstone, which for the most part lie more or less between the beds, and are proved to be intrusive by the alteration of the strata in contact with them both above and below. In their higher beds near the felstones the ordinary strata are sandy, and yield numerous fossils of the ordinary Bala species.

Both physically and palæontologically the proof is clear that these are equivalents of the Bala beds and of the Caradoc sandstone of Shropshire, and that the calcareous ashes of Dolwyddelan are the actual representatives of the Bala limestone; and in succeeding chapters it will be shown that this leads to the startling conclusion that all the vast masses of ashes that crown the felstones of Snowdon and Moel-Hebog are but an enlarged development of the same strata.

From the Moelwyns to Nant Gwynant.

North and north-west of the Ffestiniog slate quarries for about a mile, the rocks principally consist of blue slate. On the Moelwyns above the felstones there are beds of good quality, dipping north-west at angles of about 40°. The dip of the cleavage is a few degrees higher. Higher in the series, the quality of the slate seems to deteriorate. When weathered it is then of a dull rusty brownish colour, and when freshly split dark blue or blueish grey. The beds are beautifully exposed on the slopes of Yr-allt-fawr about a mile north-east of Cwm Orthin, and from the Ffestiniog and Dolwyddelan road massive beds of these strata may be seen piled on each other, dipping steadily north at angles from 40° to 60°. On the west side of Cwm Orthin, about half a mile north of Moel-y-rhudd, just about the top of the dark slates that are believed to form the Upper Llandeilo strata, a few short thin hard felspathic ashy bands are interstratified with the slate. They represent the last dying away of the thick bedded ashes of Llyn Conwy and Migneint. The beds are somewhat contorted, and greenstones partaking of these contortions are intruded among them, alike altering both ashes and slate, the latter in the crags that overhang the brook south-east of Bwlch-cwm-Orthin being changed into a kind of dark Lydianstone.

Between Moelwyn and Cynicht the slates have been described by Mr. Selwyn as "blue and grey argillaceous and arenaceous slates, with occasional thin " bands of fine-grained grey and brown sandstone."*

On Cynicht *Homalonotus bisculatus* was found and other Bala fossils in the neighbourhood. Good sections are seen on the hills round Llyn-conglog, on Cynicht, and on the road between Llanfrothen and Beddgelert. The surfaces of the beds are often ripple or current marked, and the beds occasionally undulate, as for instance around Llyn-coch, and on the road north of Llanfrothen. The general dip is however north-westerly at angles varying from 25° to 50°. In general the cleavage dips in the same direction at angles of about 70° to 80°, but about a mile north of Llanfrothen it strikes northerly, and is often nearly or altogether vertical.

One line of felspathic trap intersects these rocks on the north side of Cwm Orthin, in the manner shown in the following diagram, which represents the general arrangement of the strata on a north-west line between the syenite of Ffestiniog and the top of the hill that bounds Cwm Orthin on the north-east.

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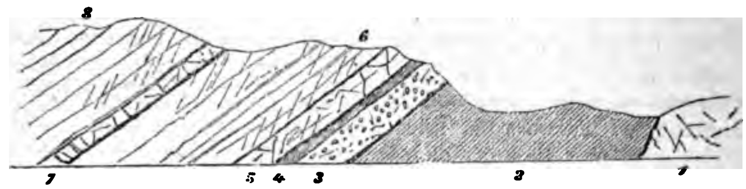
* Horizontal 6-inch section, Sheet 28, line 3, to which great part of this chapter generally applies. Also Plate 28, No. 3.

Fig. 20.



	1. Syenite.
	2. Speckled felspathic and talcose flaggy beds.
Llandeilo and Bala beds.	3. Felspathic ashy conglomerate.
	4. Slate.
	5. Felspar porphyry.
	6. Blue slate of the slate quarries.
	7. Felspathic trap.
	8. Blue slaty beds.

In places the trap No. 7 is slightly hornblendic; and though probably intruded between the beds, it may possibly be a regularly interbedded lava-flow. Besides this there are many eruptive courses of greenstone north of the Moelwyn range (Plate 28, fig. 3), forming part of a series that have been intruded into the Bala beds between Tremadoc and the west side of Cwm Penamnen.* Like others of their class in North Wales they show a general tendency to conform to the strike of the country, but in spite of this the circumstance that they sometimes almost imperceptibly cross it would alone suffice to prove their intrusive character, and their occasional more irregular branchings would place this beyond a doubt, even without the more direct evidence of the alterations they produce on the slaty rocks in contact both with their under and upper surfaces. Altogether they form a marked feature in the district, cropping out in the ten miles of hills that range between Traeth-mawr and Cwm Penamnen in more than forty spots and bands, some of which are several miles in length. Partaking of the contortions that have affected the whole country after their intrusion, it is possible that some of them may join not far beneath the surface, and only rise in different horizons by cutting slightly across the beds underground. Good examples of the effects of the undulations of the strata on the greenstones may be seen in the country immediately north of Moelwyn and west of Cwm Orthin, where, in an irregular manner, they follow all the twistings of the strata into which they have been injected. A striking example also occurs on Castell, between Cwm Orthin and Llyn-y-Ddinas, where the greenstone alike cuts across the strike, and partakes of the contortions of the country (Plate 28, fig. 3); for about two miles to the north-east, near Llyn-Edno, this greenstone is separated from the body of that porphyry by a considerable thickness of strata dipping north-west, about 25°, the greenstone also dipping approximately with the beds. Were the greenstone perfectly interbedded it would pass regularly under the outlier of Castell on the east and south, instead of which it passes *through* it and again rises with a western outcrop north of Cwm-celli-Iago on the opposite side of the axis.

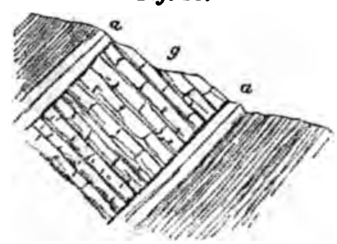
At the north end of the neighbouring outlier of Yr-Arddu one of these injected masses is crystalline and felspathic, rather an unusual circumstance with the linear injected rocks of North Wales. Rarely they seem to pass from felspathic into well crystallized hornblendic greenstone, as for instance in the band, over five miles in length, that runs from Careg-hylldrem,† north-east under the steep slope of Cynicht to Llyn-coch. Some are markedly crystalline, such as those of Moel-y-gest and the cliffs near Tremadoc, and the island-like hills of Hir-ynys and Garth that rise from the alluvium of Traeth-mawr. Finer examples still occur on the cliffs that partly bound the secluded

* Cwm Penamnen is not named on the map. It lies about five miles N.N.E. of Ffestiniog, on the way to Dolwyddelan.

† By Traeth-mawr 1¼ mile north of Llanfrothen.

tarns of Llyn-llagi and Llyn-adar,* where the slate in contact with them is altered into a spotted porcelanic substance, such as is sometimes termed "snake-stone." This is frequently the case with slates that lie close to the greenstones of Caernarvonshire, and in such circumstances they are often quarried for honestones. Some of the greenstones are nearly amorphous, and they are also in this area occasionally columnar, as on Craig-y-llyn-llagi, Bwlch-y-batel,† and by the north-east angle of the felstone porphyry of Yr-Arddu, where the columns of hornblendic greenstone lie at right angles to the dip.

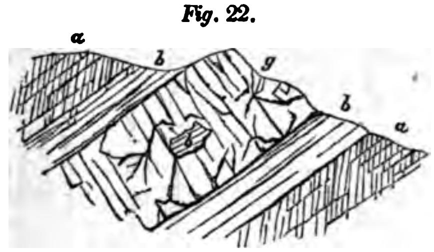
Fig. 21.



g. Greenstone. *a.* Altered slates.

Good examples of the greenstone and its effects may be seen on Moel-dannogen and at Bwlch-y-gerddinen on the road from Ffestiniog to Dolwyddelan. The rock is an ordinary greenstone, very hornblendic, and largely crystalline, and the slates both above and below the mass are porcelanised, flaky, and speckled like "snake-stones." Some slaty included fragments are also speckled, and others, which like these have been caught up and included in the greenstone during its intrusion, have the appearance of felspathic trap. The slates all round are highly cleaved, with the exception of the bands in the immediate neighbourhood of the greenstone.

Fig. 22.



a. Cleaved slate. *b.* Altered slate uncleaved.
g. Greenstone with included fragments of slate *b.*

This greenstone, like others of its class, was intruded into and altered the slates before those disturbances took place that heaved and contorted the strata into their present inclined positions, and also produced the cleavage; and it is clear that the altered porcelanic character of the rocks in contact with the greenstone prevented their being cleaved. If, as I believe, cleavage has been produced by intense lateral pressure during disturbance of the strata, then it would appear that the excessive hardness and compactness of the altered rocks in this instance hindered the particles from being re-arranged so that their major axes should lie in lines at right angles to the pressure, thus originating a tendency to split in a certain direction, which constitutes cleavage; whereas in the softer rock this change of position of the particles was readily produced.

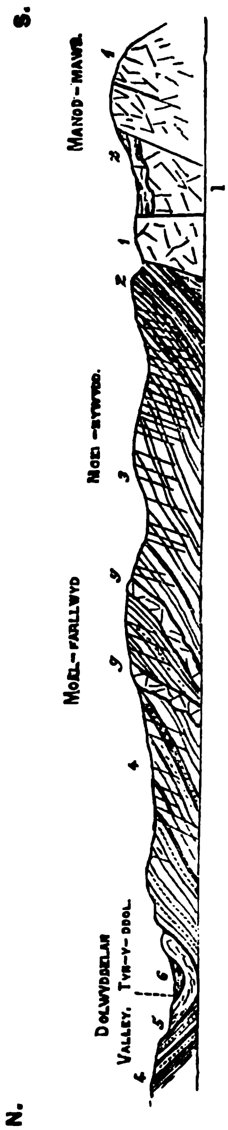
Dolwyddelan. — The following diagram explains the general structure of this country between Manod-mawr, near Ffestiniog,

* Between 3 and 4 miles east of Beddgelert.
† Three miles E.S.E. of Beddgelert.

and the valley of Dolwyddelan, and especially illustrates the circumstance that thick accumulations of slate separate the igneous rocks of the Arans, the Manods, and Moelwyn from those of Dolwyddelan and Snowdon.

Fig. 23.

SECTION ACROSS THE BALA BEDS FROM MANOD-MAWR TO DOLWYDDELAN.



1. Lower felspathic porphyry of Llandeilo age, the equivalent of the Arans, Arenig, and Moelwyn.
2. Blue slate and felspathic ash between two faults, including part of the Ffestiniog slate quarries } Llandeilo beds.
3. Blue slaty rock
4. Slate and sandstone, very fossiliferous
5. Upper felspathic porphyry and ash of the Caradoc or Bala beds
6. Calcareous ash, the equivalent of the Bala limestone. 5 and 6 are equivalent to the rocks of Snowdon, Glyder-fawr, Moel-Hebog, &c. } Bala beds.

g. Greenstones often intruded in the lines of bedding.

Beyond the Moel-dannogen and Moel-farllwyd greenstones the Bala beds dip steadily north towards the valley of Dolwyddelan at angles ranging between 20° and 60°. They consist of arenaceous slate and sandstone (No. 4 Diagram, No. 22), and are generally fossiliferous, especially in the upper part of the series, approaching [redacted]

less cleaved, the cleavage following the general strike of the country, and like the beds (but often at higher angles) dipping northerly at angles of from 60° to 70°. The following are the common fossils of the neighbourhood:—

Nebulipora lens; Asaphus Powisii, Homalonotus bisulcatus, Cythere umbonata Orthis flabellulum, O. calligramma, O. elegantula, and *O. vespertilio, Strophomena expansa, S. grandis, Leptæna sericea, Orthonota quadrata, Ctenodonta lævis* and another, *Murchisonia simplex Bellerophon bilobatus,* &c.

The igneous rocks of the valley of Dolwydellan lie in an elongated basin ranging from Yr-Arddu on the west to Y-Fedw on the east. On the south, the Bala beds dip under them at angles varying from 45° to 80° near Hendre; and on the north, on the slopes that rise towards Moel-Siabod, the same rocks dip southerly at similar angles. The trap consists of blue felstone weathering grey or yellow, and it is partly overlaid by and partly includes a mass of dark blue ferruginous slate, the cleavage of which follows the strike of the country, and is nearly vertical, or dips southerly 80°. The bedding is obscure but probably dips north, and the rock has been worked for slate in several places between Dolwyddelan and Tyn-y-ddol. The branching manner in which the felstone is associated with this slate might at first sight seem to indicate its intrusive character; but it can be easily imagined how successive flows of lava might coalesce at one end, while interstratified mud was deposited on other parts of the lava current in the intervals of eruption. Besides this, the felstone is regularly overlaid by a highly calcareous brown ash between Castell-Dolwyddelan and Yr-Arddu; and this rock (except that it is often more calcareous) is identical in structure and position with the ashy beds that overlie the interbedded felstones of Snowdon, Y-Glyder-fawr, and Moel-Hebog. This ash is in places fossiliferous, somewhat felspathic or sandy, and conglomeratic, containing pebbles as large as an egg, and sometimes so very calcareous that it weathers precisely like portions of the Bala limestone on the south-east and north of Bala. From its position and lithological character, Mr. Jukes, Mr. Selwyn, and myself were all of opinion that it is the actual representative of that limestone itself. Diagram No. 23 shows that it occupies the same general position with reference to the Manod and Moelwyn porphyry that the Bala limestone does to those of Aran-Mowddwy and the Arenigs; and the felstone and felspathic ash of Dolwyddelan may in some sort be considered the representatives of the ash that lies close beneath the limestone in part of the Bala district, or more especially of the felspathic rock that immediately underlies the same limestone on Pen-llech, about two miles east of Penmachno.*

The thickness of the beds between the two sets of strata is in both cases approximately the same, and it will be observed that in

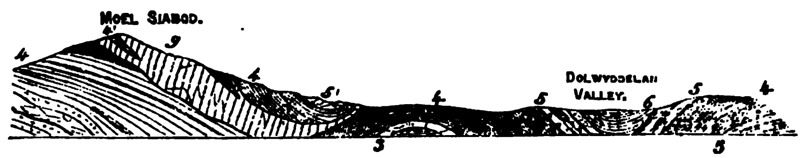
* Horizontal section, Sheet 31, line 4.

both districts the upper portion is sandy and fossiliferous, the lower beds being formed of dark blue and generally unfossiliferous slate, believed to represent the upper part of the Llandeilo flags.

Fig. 24.

SECTION ACROSS THE BALA BEDS FROM DOLWYDDELAN TO MOEL SIABOD.

N.W. S.E.



3. Felspathic porphyry.
4. Grits and slates, fossiliferous, Bala beds.
5. Felspathic porphyry - - - } Equivalents of the porphyry and ashes of Snowdon.
6. Calcareous felspathic ashes, equivalent of the Bala limestone - - - - }

Moel Siabod.—Between Dolwyddelan and Moel Siabod the fossiliferous beds, No. 4 of the above diagram, rising in the moorland from beneath the igneous rocks of the valley, roll over to the north, about half-way up the mountain, and the felstone No. 5′ is caught, in two small patches, in a kind of inclined basin, which runs from the south-west of Moel Siabod to Llanuwchlyn on the left bank of the Conwy.

The higher part of Moel Siabod is formed of a great mass of intruded greenstone (*g*), often columnar, which forms the crags that overlook Llyn-y-foel, in the deep recess on the east slope of the mountain. On the south-west this greenstone commences near Llyniau-duwaunedd, and branches into two at the summit, where the slaty rocks are highly altered between the forks (No. 4′). The longer branch strikes north-easterly, and crosses the Holyhead road near Dolbryn. The whole dips to the south-east, and cutting across the beds, again rises in this synclinal on a slightly different horizon in the long strip that runs from the twelfth milestone on the Holyhead road to Afon-ystymiau. A similar appearance of the greenstone occurs further west, supposed to be connected with the main mass in the manner shown in the above diagram; and it seems possible that these and the other patches that break out on the slope of the hill are all connected at no great depth beneath the surface. Like others of their class, having been injected before the contortion of the country took place, they are necessarily affected by its curves.

CHAPTER XVI.

THE BALA BEDS AND INTERBEDDED IGNEOUS ROCKS BETWEEN BETTWS-Y-COED, MOEL-SIABOD, LLYN-OGWEN, AND CONWAY, AND THE INTRUSIVE MASSES BETWEEN CONWAY AND Y-FOEL-FRAS.

General Description. — North of Moel-Siabod the Bala beds assume a markedly different character from that which they possess between Dinas-Mowddwy and Dolwyddelan, for they become [redacted]

mixed with a much greater number of beds of interbedded felstones and volcanic ashes, which range northward to Conway, and from thence south-west along the higher Caernarvonshire mountains. Y-Foel-frâs, Carnedd-Llewelyn, Carnedd-Dafydd, Y-Glyder-fawr, Snowdon, and Moel-Hebog, are the chief mountains in this the wildest and grandest part of North Wales; and these, like the ranges of Cader Idris, the Arans, and Moelwyn, consist in a great degree of volcanic products. It has been stated that these volcanic rocks belong to two sections of the Lower Silurian period, for the the felstone porphyries and felspathic ashes, and perhaps even the intrusive greenstones of Merionethshire, were formed during the deposition of the Llandeilo strata, while the same species of thick-bedded traps and ashes on Snowdon and the surrounding mountains are high in the Bala or Caradoc series. In both cases they form the highest mountain ranges in Wales, not from upheavals caused by the *intrusion* of igneous masses in special areas, but simply from the circumstance that long after their formation, while lying deep below thousands of feet of newer strata, the whole of the Lower Silurian and Cambrian rocks of the area have been disturbed together, and rolled into great curving lines; and the hard felspathic igneous masses now rise so high, because they have better withstood degradation than the slaty rocks with which they are interbedded. It is worthy of remark that the ranges formed of the lower porphyries, &c., of Cader Idris, Aran Mowddwy, Arenig, and Moelwyn, lie midway up in the strata of the great Merionethshire anticlinal, while the peaks of the still higher range of Moel-Hebog, Snowdon, and Carnedd-Llewelyn, actually lie in the middle of a basin. (Section No. 3, pl. 28). The whole form but minor parts of an old mountain system of which Wales is only a fragment.

The Mountains North of Capel Curig.

I shall now describe the rocks of part of Caernarvonshire between Bettws-y-Coed, Moel-Siabod, Llyn-Ogwen, and Conwy.

At first sight it requires an effort to believe that most of these rocks are the actual equivalents of the slender band of Bala limestone, near Bala, and of the slates and insignificant ashy bands that underlie it. Nevertheless, alike physically and palæontologically, the evidence is clear; and only in one or two spots on the banks of the Conwy do any of the rocks of that large area rise a little higher than the parallel of the Bala limestone; while by far the larger part is either on or a little below that parallel. It is not, indeed, till we reach the neighbourhood of the village of Llanberis and the middle of Nant Francon, far below the falls of the Ogwen, that we get as low as the horizon of the Arans and Arenigs, and find that their lavas and ashes are utterly unrepresented in Caernarvonshire.

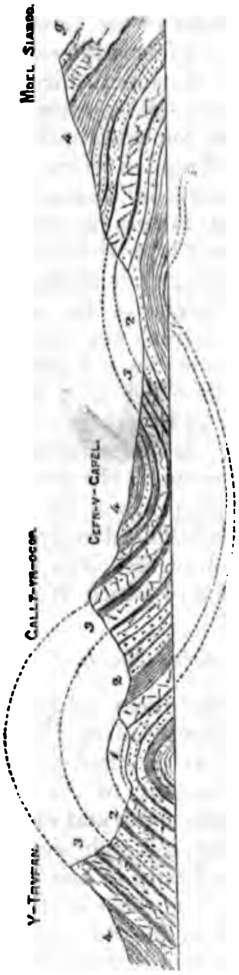
Moel Siabod and Y-Tryfan.—Descending on the northern side of Moel Si[illegible] the green slopes consist, first, of slaty beds, and, lower down in the [illegible] region, of largely bedded grits (4, Fig. 24) that overlook the valley of N[illegible]

gwyrd. They are the equivalents of the beds between Dolwyddelan and Moel-farllwyd (Fig. 23), and contain *Stenopora fibrosa, Asaphus Powisii, Orthis elegantula, Murchisonia simplex, Orthocerata*, and other Bala fossils. In the midst of the grits there appears a bed of felspathic trap, which does not rise on the south side of the synclinal curve of Dolwyddelan. Its position is represented in the following diagram, which may be considered a continuation of the last.

Fig. 25.

Section across the Bala Beds from Moel Siabod to Y-Tryfan Llyn Ogwen.

N.W. S.E.



1 and 3. Felstones.
2. Grits }
4. Slates and grits } Fossiliferous Bala beds.
g. Greenstone.

The felstone (No. 3) rolls over in an anticlinal axis, as drawn on the maps* and sections, and curves round in an oval form immediately south-west of Capel Curig, including in its sweep the lakes of Llyniau Mymbyr. The rocks in front of the hotel form part of it. On the north side of the road it splits into three bands, and passing under the slates and grits of Cefn-y-Capel, it again rises in three masses in the cliffs of Gallt-y-gogo, or Gallt-yr-ogof, two miles

* 78 S.E. and 75 N.E.

west of Capel Curig. These are rolled over in a bold anticlinal, about two miles wide, and form the sharp peak of Y-Tryfan, where, on the eastern cliff, a good eye can easily detect, from the valley below, three beds of felspathic porphyry interstratified with slate, dipping west at an angle of about 60°. Two great upright stones, placed by nature, stand on the top of the mountain. The eastern cliff, which is not easily accessible, is bare, and largely jointed, and the west slope, besides being steep, is cumbered with immense masses of stone, which, piled on each other, render the ascent somewhat difficult, except to accustomed mountaineers. Fossiliferous grits (No. 2) underlie this, and in the midst of them there is a bed of felspathic porphyry, marked No. 1. Y-Glyder-fach is a continuation of the felstones of Y-Tryfan, as shown on the map. It is peculiarly rough and craggy, and the weary barren slopes that sweep round above Pen-y-gwryd are covered with huge blocks of felspathic porphyry, tufted with moss and heath. There the trap and overlying grits, partly ashy and brecciated, dip W.S.W. and south-east, curving round in an oval form to join the same rocks on Gallt-y-gogo (or Gallt-yr-ogof), and the whole lie about 400 feet below the igneous rocks of Snowdon, afterwards to be described (pp. 108 and 111, figs. 29 and 30).

From Gallt-y-gogo the same felspathic band strikes north about eight miles, passing through the lakes of Ffynnon Llugwy, Melynllyn, and Llyn-dulyn. Beyond Pant-glas, four and a half miles E.S.E. of Aber, it is thrown, along with other rocks, to the north-west in a succession of blocks, by seven faults that lie between the Llanbedr and Aber fault and the neighbourhood of Conway. Here also a great lower mass of felstone porphyry extends between Conway mountain and the carns of Y-Drosgl north of Y-Foel-frâs. (*See* Maps.)

If on the opposite side of the anticlinal bend we trace the rocks of Y-Tryfan northward, we shall find that the two higher beds of its felstone strike through Ffynnon-y-lloer to the top of Carnedd Dafydd, where they curve round to the south with an eastern dip, and entirely thin away on the rugged slope of Craig-yr-hysfa above Nant Francon. In the midst of the anticlinal (which may be likened to a dome) there is a lower oval-shaped line of felspathic rock with a quaquaversal dip. Grits underlie and slates overlie it. Amid these, on the north, is a short bed of felstone passing into the hill in the form of the letter V reversed. Both of these, passing beneath the grits west of Ffynnon Llugwy, rise again along the east side of Carnedd Llewelyn. The higher strikes north for about three miles; the lower is cut off by the greenstone of Cefn-yr-Arryg. In the opposite direction, partly broken by faults, they curve along the north side of Carnedd Dafydd, then striking southwards through Craig-yr-hysfa they reach Nant Francon, less than half a mile below the bridge. It will be observed that this curve forms the northern spoon-shaped end of a synclinal axis, which bends upwards to the east and west between Cwm-Tryfan and Nant Francon,* and it is worthy of remark that none of these minor beds, and only a trifling representative of the immensely thick interbedded porphyries of Y-Tryfan and Y-glyder-fach (diagram 26) come up with the western rise of the synclinal curve on the Llanberis side of Nant Francon, so that about 1,600 feet of these lavas thin away in little more than a mile between the east end of Llyn Ogwen and the banks of the river a little below the Falls.

Fossiliferous grits and slates both overlie and underlie the felstones of Y-Tryfan and Gallt-y-gogo (Figs. 25 and 26) throughout all their range from the upper part of the Pass of Llanberis to the neighbourhood of Conway. From the Pass the higher grits and slates regularly accompany the felstone of Gallt-y-Gogo in its northern strike. On Cefn-y-Capel these are principally arenaceous slates, except one marked bed of grit near the base. North of Cwm-tal-y-braich, they gradually become more sandy,† and on the hills west and north of Clogwyn, near Llyn Eigiau, they resolve themselves into several distinct bands of slate and grit, containing numerous casts of ordinary Bala fossils. West of Y-Tryfan, on either side of Llyn Ogwen, the same beds are also fossiliferous. The lower gritty beds of the anticlinal curve are well exposed, sweeping round the top of the valleys in magnificent terraces, underneath the

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* The continuation of this synclinal line forms the basin in which Snowdon lies, described at p. 109.

† Two and a half miles west of Capel Curig.

felstones of Gallt-y-gogo, Y-glyder-fach, and Y-Tryfan. At the very base, close by the old road between the farms of Wern-go-isaf and Wern-go-uchaf, the flattened centre of the anticlinal may be seen rolling over to the east and west (Fig. 25).

The following fossils were collected from these strata by Mr. Salter:—*Stenopora fibrosa, Cornulites serpularius, Rhynchonella serrata,* a small *Lingula,* and *Modiolopsis.*

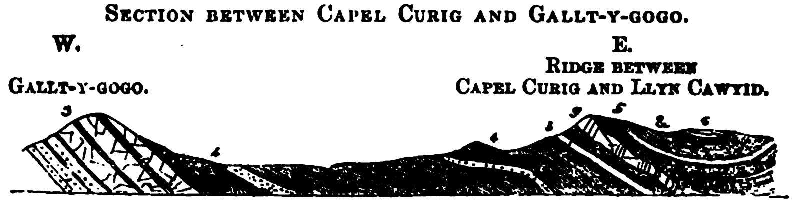
Capel Curig.—East of the long lines of felstones, slates, and sandstones that strike from Gallt-y-gogo towards Conway, there lies between Llyn Cawlyd, Llyn Eigiau, and the river Conway, a slaty country, with greenstones and interbedded felspathic rocks, the relation of which to the other rocks I shall now briefly describe.

North of the Holyhead road between Bettws-y-Coed and Capel Curig there is a broken rocky escarpment, formed of interstratifications of felspathic rocks and slates. With minor undulations the general strike of these is east and west as far as the hills that overlook Capel Curig, where they suddenly bend round and strike north to Llyn Cawlyd* in a bold picturesque ridge. Between Bettws-y-Coed and Llanbedr on the left bank of the Conwy there is another high escarpment formed (in general terms) of the same set of rocks. The intervening space between the Conwy and Llyn Cawlyd thus consists of a kind of undulating tableland intersected by valleys and lakes, rarely visited by the tourist, some of which are mere reedy pools, and others, such as Llyn Geirionydd and Llyn Crafnant, are of larger size, and possess a pastoral beauty almost peculiar to themselves in Wales. Above the porphyry that encircles Llyniau-Mymbyr the ascending section north-east of Capel Curig is as follows:—First, certain slaty beds that contain a short thick band of conglomeratic ash, which forms a little rocky hill close to the road nearly opposite the turnpike gate, and strikes northwards about half a mile, when the ash disappears. Eastward of this as far as Clogwyn-manod there are four or five beds of interbedded felspathic ashes, the highest of which forms a little outlier, and consists of felspathic matter mingled with the ordinary mud of the period.

The section between Gallt-y-gogo and the rocks of this ridge is as follows, Gallt-y-gogo itself being formed of the equivalent of the felstone rocks that encircle the lakes of Capel Curig.

Fig. 26.

SECTION BETWEEN CAPEL CURIG AND GALLT-Y-GOGO.



3. Three beds of felspathic porphyry overlying fossiliferous grits, and interstratified with slate.
4. Slate and grit of Cefn-y-Capel, fossiliferous.
g. Greenstone intruded between the beds of slate, which are changed into porcelanite both above and below.
5. Bedded felspathic traps, and
6. Ashes interstratified with slates.

Further north the same rocks on the slope above Llyn Cawlyd present a similar arrangement, and the same may be said of the rocks between Llyn Bodgynwydd, Llyn Goddion-duon, and the Holyhead road, about half-way towards Bettws-y-Coed. By inspecting the larger map (78 S.E.) it will be seen that some of the beds of felspathic rock in this district thin out in lenticular forms, being not more than half a mile in length.

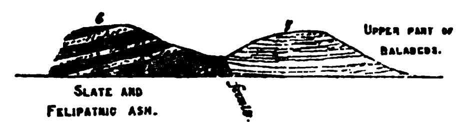
The topmost igneous bed by Llyn Goddion-duon immediately above the Holyhead road is the equivalent of the outlier of Clogwyn Manod. Its charac-

* Mis-spelt Cwlyd on the map.

ter is peculiar, consisting of a dark blue or black slaty base containing numerous scattered crystals of yellow felspar, which gradually increase in quantity as we follow the bed till at last the slaty impurities entirely disappear, and north of Llyn Bodgynwydd it becomes an ordinary felspathic ash. East and north of this lake it widens, capping the whole summit of Pen-uchaf-y-gwaith, from whence striking northwards, it is lost under the alluvium of the Conwy at Ysgubor-gerig about half a mile south of Trefriw. An outlier of the same rocks skirts the woods of Llyn-y-parc on the west, and a north and south fault, that strikes along Nant-Gwydir and the lake, throws down a higher part of the Bala beds against the ash and interstratified slates.

Fig. 27.

W. NANT GWYDIR. E.



6. Ash and slate.
7. Bala beds above the equivalents of the Bala limestone.

In many parts of its range south of Trefriw the ash is highly porphyritic, distinct, imperfect, or broken crystals of felspar being embedded in a base, which weathers brown at the surface. At Cwm-lanerch about two and a half miles south of Llanrwst these higher Bala rocks are full of *Trinucleus concentricus*, *Leptæna sericea*, and other common Bala fossils.

On the opposite side of the synclinal, west of Llanrhwchwyn, the same ash bed skirts Llyn Geirionydd, striking north about a mile beyond Bedd Taliesin, and from thence, with many branchings, it curves round and thins out about a quarter of a mile north-east of the efflux of Llyn Cawlyd. The whole country is full of injected greenstones, which, without narrow inspection, might be supposed to be interbedded in the same manner as the felstones. This is especially the case on the hill that overhangs Llyn Cawlyd, where bands of slate, felstone ashes, and greenstone alternate with great regularity; but on close inspection it is found that these greenstones here and there branch in dyke-like fashion into various horizons, and also that whereas the slates are quite unchanged when only associated with felspathic ashes, in contact with the greenstones they assume a porcelanic texture both above and below the injected rock. These porcelanites weather white, like the felspathic rocks, and I found it no easy matter to separate the two while mapping the country between Pen-uchaf-y-Gwaith, Llyn Cawlyd, and Capel Curig. The same may be said of the country east of Llyn Eigiau, mapped by Mr. Aveline, and these facts, added to the contortion of the beds and the incessant appearance and disappearance of felspathic interstratifications, rendered this country peculiarly tedious and difficult to unravel.

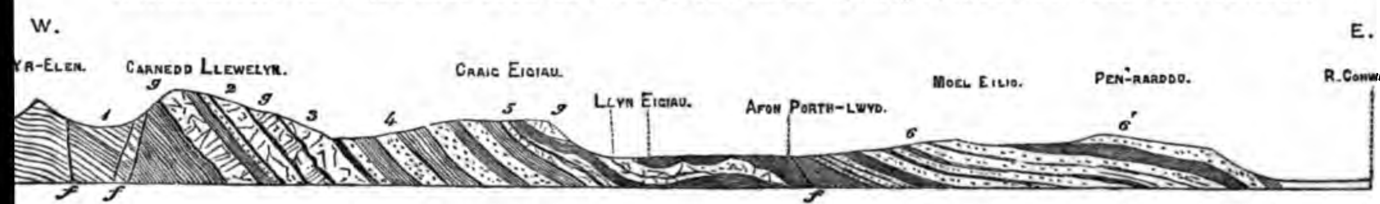
Carnedd Llewelyn, the Vale of Conwy, &c.—North of Trefriw the same bed of volcanic ashes that dips under the alluvium of Ysgubor-gerig, reappears on the left bank of the Conwy between the fourth milestone and Llanbedr, and forms all the high ground for about a mile in width from Pen-'r-arddu and Gallt-y-rhiw to Pen-y-gaer and Llanbedr, where it is cut off by two faults, downthrows, on the south-west and south-east.

The whole in places becomes a porphyritic conglomerate or breccia, fragments of felspathic lava being embedded in a porphyritic felspathic base. Some of its beds are finer grained and of a dark hue, decomposing brown at the surface, while others are of a light grey tint, when the rock is freshly fractured. At its southern end it is faulted, and abuts against a solid bed of pinkish-white felspathic porphyry.

About three miles, by the map, east of the Penrhyn slate quarries there is a st[illegible] conical slaty hill called Yr-Elen. A section drawn east from this hill thro[illegible] Llyn Eigiau, and over Pen-r-arddu to the river Conwy, gives the same ge[illegible] arrangement of beds as that immediately east and north of Capel Curig.

Fig. 28.

SECTION ACROSS THE BALA BEDS FROM YR-ELEN TO THE RIVER CONWY, BETWEEN LLANBEDR AND TREFRIW.



1. Slaty beds of the Bala series underneath the parallel of the Bala limestone, faulted, but on the whole dipping east.
g. Intrusive masses of greenstone forming a large part of Carnedd Llewelyn, and of the cliff above Llyn-Eigiau.
2. and 3. Beds of interbedded felspathic porphyry, the upper bed of which is the equivalent of the felstones of Gallt-y-gogo (figs. 25 and 26). They are interstratified with fossiliferous grits.
4. Fossiliferous grits and slates, equivalents of the rocks of Cefn-y-Capel, and the north-west side of Moel Siabod (fig 24).
5. A thin bed of felspathic ash.
6 and 6'. Slate overlaid by and interstratified with beds of felspathic ashes.
f. Faults.

[redacted]he ashes No. 6 and 6′ are the general equivalents of those above the felstones of Dolwyddelan, and therefore the representatives of the [redacted]la limestone and of the top of Snowdon. The slates of Llanrwchwyn and Cefn Careadwydd immediately overlie it, and form one of the [redacted]hest portions of the Bala beds in this part of North Wales.

Opposite Llanrwst two faults coalesce and pass up the vale of Conwy under e alluvium to Llanbedr, near which the fault branches in several directions, ie branch passing towards Conway by Y-Ro, another towards Penmaen Mawr, id a third to Aber. A fourth fault joins it at Pen-y-gallt near Llanbedr, and riking south-west by Yr-Elen, Llanberis, and Llanfihangel-'y-pennant, is lost Cardigan bay near Criccieth. It cuts across the interbedded felspathic trap ' Carnedd Llewelyn and grit (No. 2, 3, fig. 28) between Y-Foel-frâs and lyn Dulyn, throwing them slightly down in the south. Beyond this dislocan these rocks still strike to the northwards, dipping easterly at angles from P to 60°. At the upper part of Afon Ro they are affected by the Aber and lanbedr fault, which is there a downthrow, on the north; and between this int and Conway the course of the same bed of felspathic porphyry and overing fossiliferous grits is disturbed by ten faults, each in succession throwing iem a little further to the north-west.

The grits are overlaid also by beds of felspathic ashes accompanied by numeous bands of greenstones, intruded more or less in the line of strike. The hole, as near as may be, form the equivalents of similar rocks that, south of lanbedr, lie between the Conwy and the east slope of Carnedd Llewelyn, and allt-y-gogo two miles west of Capel Curig.

Conway.—North of Conway, interstratified with slates, these rocks rest n the felspathic mass of Conway mountain, dipping south at angles of bout 60°. In the estuary they are cut off by a fault which is a downthrow on ie east, and on the west they are thrown by another dislocation against the ap of Penmaen-bach and Dinas. Another fault cuts off the grits on the south, irowing down higher beds against them, which are calcareous, and contain iany of the ordinary Bala limestone fossils, usually in a fragmentary state. 'onway Castle is built on one of these beds, dipping south at an angle of 60°, nd the same grits occur on the opposite bank of the estuary, near the trap of)iganwy and east of Bryn-y-Gosol. It is there of a dark blueish grey hue, alcareous, and slightly conglomeratic, containing numerous rings of *Encrinites* nd casts of *Orthis*.

These rocks lie amid black slates, and are much contorted and altogether ounded by faults. They are probably equivalent to some of the higher strata etween Trefriw and Llyn Geirionydd and of the Bala limestone. The whole re much obscured by drift; and north of Conway they are overlapped by the Carboniferous limestone which on Great Ormes Head creeps across the strike, nd passing underneath the sea to Anglesea, at the entrance of the Menai Straits, it lies on Silurian strata much beneath the rocks near Conway.

Penmaen-mawr, &c.—West and south-west of Conway there are three great masses of felspathic porphyry, forming the shingly heights of Penmaen-bach, Penmaen-mawr, and Dinas. The rock is of a blueish grey tint, and chiefly consists of small felspar crystals, occasionally associated with a very small proportion of hornblende. Where visible, the black Silurian slates in contoct with them are much altered; and though the form of the ground seems to indicate that the rock of Penmaen-mawr rests upon the slate with a northern dip, yet the massive and crystaline character of the rocks of the three heights named above, and their boss-like forms, shows that they are intrusive masses, and not interbedded felspathic lava-flows.

Between Penmaen-bach and Y-Drosgl, about 3 miles east of Aber, a broad thick sheet of felspathic porphyry overlies the slate in which these intrusive masses lie. Occupying a given horizon, and being both underlaid and overlaid by continuous bands of slate, with which it dips east and south-east, there can be little doubt of its true interbedded character. On the south it is cut off by the Aber and Llanbedr fault, and abuts on the massive porphyry of Y-Foel-frâs, with which it is not unlikely that it may have been originally connected —the great boss forming an underground volcanic centre, and the interbedded rock being one of the lava beds that proceeded from it. Of the intrusive nature of the porphyry of Y-Foel-frâs there can be no doubt, for wherever slates are seen in contact with its unfaulted boundary they are highly altered. At the cascade above Aber, this porphyry forms the rock over which the water falls. Close to this point the strata have been changed to a kind of quartzite, and in other places near they have been baked into porcelanite. Receding from the trap, they rapidly pass into common slate. The stratification at this point is obscure, but it seems probable that bedding and cleavage

coincide, being nearly vertical, or dipping sometimes towards and sometimes from the porphyry at angles of from 80° to 85°. The igneous rock rises through like a wall on its north-west boundary. At its edges it is often fine-grained and weathers yellow, and it appears not unlikely that this may be due to the circumstance that some of the melted mass may actually consist of fused Silurian strata for highly altered slates are often almost indistinguishable, even when fractured, from compact felstones. Beyond this yellow band the rock assumes something of the character of a greenstone, crystals of felspar and hornblende being intermingled, although the former generally much predominate. Further in still, the great mass may be described as a felspar porphyry, numerous well-defined crystals of felspar being embedded in a felspathic base sparingly associated with hornblende. In several places, however, it becomes a true hornblendic greenstone, and all the varieties pass gradually into each other.

Equivalents of the Bala Limestone, &c.

I have stated that the beds west of the Denbighshire sandstone between Capel-Curig, Bettws-y-Coed, and Conway, are the true equivalents of the beds immediately associated with the Bala limestone, and that some of them represent that limestone itself. The absolute proof is as follows:—

It has been shown (pp. 98 to 00) that the calcareous ash of the valley of Dolwyddelan is the equivalent of the Bala limestone, and its position with reference to the fossiliferous grits and interbedded felspathic trap around Llyniau-Mymbyr near Capel-Curig is explained in Diagrams Nos. 23 and 24.* But the Llyniau-Mymbyr porphyry being equivalent to that of Gallt-y-gogo, and the great bed that runs from thence towards Conway, it is evident from a consideration of Diagrams Nos. 25 and 26 that the ashes and

Fig. 29.

Section across the Bala Beds from Dolwyddelan to the Rocks North-west of Bettws-y-Coed.

No. 6, calcareous ash and slaty beds on the south part of which is the equivalent of the Bala limestone. 5. Felstone. 4. Fossiliferous slates and gritty Bala beds underlying the Dolwyddelan felstone, and equivalent to the grits and slates of Moel Siabod, marked No. 4 in Figs. 24 and 25. 3. Felspathic porphyry (the equivalent of No. 3 of Figs. 24, 25, 26). It rises from beneath No. 4, and is exposed by denudation in Glyn Lledr, where it rolls over in an anticlinal curve on either side of the valley, so that the slates No. 4, on the river {Llugwy are again capped by felspathic ash and slate, No. 5′ and 6′, between the river and Pen-uchaf-y-gwaith. These are evidently by position the equivalents of the rocks Nos. 5 and 6 in the valley of Dolwyddelan, and therefore of the Bala limestone.

* Also the Sheet of Horizontal Sections, Sheet 31, line 3.

slates north of the road between Capel-Curig and Bettws-y-Coed bear the same relation to it that the Dolwyddelan calcareous and felspathic ash does to the trap of Llyniau-Mymbyr. Further, if we construct a section from Dolwyddelan north-east to Glyn-Lledr, and from thence north to Pen-uchaf-y-gwaith, a mile south of Llanrhwchwyn, near Llanrwst, the arrangement of the rocks is as shown in fig. 29.

A glance at the map shows that the same part of the Bala beds is continuous from thence along the left bank of the Conway to the mouth of that river, as already described; and at Conway itself, in the very same position with regard to the traps and grits of Conway mountain, there occurs the calcareous fossiliferous grit, which lies in the place of the Bala Limestone, and I believe is its absolute equivalent.

CHAPTER XVII.

The Snowdon Area and Moel Hebog.

General Description.—The felstones and ashes of the Snowdon area form the most important members of the igneous series of Caernarvonshire. Indeed, the grandest part of this country, both as regards the scale of the igneous phenomena, and the consequent magnificence of its scenery, is owing to the hard and soft layers concentrically interbedded in a great trough shown in the easterly dips of the slates, grits, and traps on the flanks of Moel-Hebog, Snowdon, Y-Garn, and Carnedd-Dafydd; while the opposite inclination of the rocks on the summit of Y-Glyder-fawr, Y-Tryfan, and part of Carnedd-Dafydd, forms the eastern side of the basin. This trough contains within itself several smaller undulations, and the highest of its beds is on the parallel of the Bala limestone, and the whole area forms an inner part of a much greater synclinal curve shown in the general south-easterly dip of the Cambrian and Lower Silurian strata north-west of Carnedd-Llewelyn, Snowdon, and Moel-Hebog, and in the average north-westerly inclination of the strata of the Moelwyn range and the Cambrian beds below. Between Llyn-Ogwen and the Manods, indeed, the simple form of the basin is in a manner lost in the subsidiary undulations of Dolwyddelan, Nant-y-Gwyrd, and Cwm-Tryfan, but on a large scale it exists. The whole country may be likened to a crumpled sheet of paper, to the folds of which a general but irregular direction has been given, and in which some of the larger

trough-shaped bends are interfered with, and die out, in consequence of the appearance of other anticlinal and synclinal curves.

By carefully considering these curves, the identity of the Snowdon rocks with those of Dolwyddelan is proved, thus directly linking both to the horizon of the Bala limestone. The following is the proof:—

Snowdon and Dolwyddelan.—It has been already stated* that fossiliferous grits rise on the south and north from under the felstones of Dolwyddelan. At the west end of the valley the same strata rise from under the porphyry of Yr-Arddu, and rolling over to the west plunge at angles of from 10° to 25° beneath the felspathic porphyry of Cerrig-Cochion and Cribiau, east of Llyn-Gwynant. The grits and overlying felspathic rocks are therefore equivalents. But a glance at the map and the following diagram, No. 30, will show that the felstones of Cerrig-Cochion and Cribiau form part of that mass which circles round and constitutes a great proportion of Snowdon, and that it is overlaid by calcareous and felspathic ashes. These ashes therefore stratigraphically bear the same relation to the Snowdon and Cerrig-Cochion felstones that the calcareous ashes of Dolwyddelan do to the underlying porphyry there, and the rocks of Dolwyddelan form therefore an outlier of the larger mass of Snowdon and Nant-Gwynant. A line of section drawn from the Dolwyddelan basin across Llyn-Gwynant, and from thence to the top of Snowdon, gives an arrangement of the rocks as shown in fig. 30.

On the south-east the ash No. 6 consists of "a greyish green "or green and white spotted rock, very calcareous, and decomposing into a soft brown earthy substance similar to an ashy bed "that in places accompanies the Bala limestone:"† or, not unlike the limestone itself, where it is occasionally somewhat mixed with volcanic substances. At the west end of the valley it lies on the mass of felspathic porphyry (5), which contains well-formed separate crystals of white felspar, and forms the hill of Yr-Arddu. Beds of fossiliferous greenish grey grits and slates rise (4) from under it, which, rolling over to the north-west again, dip under the slaggy-looking felspathic trap of Cerig-Cochion (5), the weathered surfaces of which show beautifully contorted lines of the kind described at p. 123. West of Cerig-Cochion and Cribiau the ash (6) dips downwards into the valley of Nant-Gwynant, and rising on the flank of Snowdon it rolls across Cwm-Llydaw in a denuded anticlinal curve, and is caught again on the peak of Snowdon above the felspathic porphyry (5). On Gallt-y-wenallt an upper felstone *c* (which will be subsequently described) just tips the ashy rocks, and both ash and lower porphyry gradually thicken between Dolwyddelan and Snowdon. Beneath the porphyry at Cwm-y-Clogwyn coarse grey grits (4) rise to the surface, the general equivalents of those between Yr-Arddu and Cerig-Cochion. A line of greenstone *g* pierces the rocks in Cwm-y-Clogwyn.

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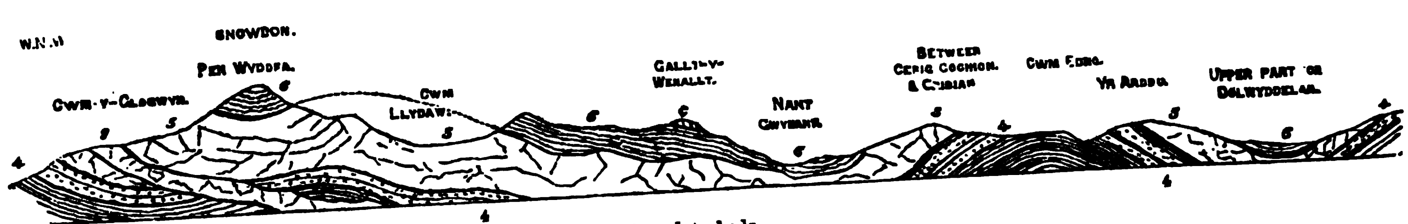
* Pp. 98 to 100. † A. R. Selwyn, MS.

Fig. 30.

SECTION FROM THE VALLEY OF DOLWYDDELAN TO SNOWDON.



4. Grits, fossiliferous, overlying slaty beds.
5. Felspathic porphyry (lava beds).
6. Volcanic ashes, sometimes calcareous and fossiliferous = Bala limestone.
c. Columnar felspathic trap.
g. Greenstone (intrusive).

The above diagram clearly shows that the ashes, porphyry, and grits of Dolwyddelan and Snowdon are the same, and the calcareous ash of Dolwyddelan being the equivalent of the Bala limestone,* the ashes of Snowdon also belong to the same geological horizon, while the rocks both of Snowdon and Dolwyddelan collectively are the general equivalents of the complicated interstratifications of slates and igneous rocks that run from the Capel-Curig and Bettws-y-Coed to Conway.†

Snowdon and Nant Gwynant.—Before describing the underlying rocks in detail, I shall give an account of the general lithological characters of the ashes on and around Snowdon. As a whole, they are well stratified, and in many respects resemble those that underlie the older prophyries of Aran Mowddwy and Cader Idris.

It should be understood that it is not implied that from top to bottom they are formed of good typical volcanic ash or tuffa. On Snowdon they are partly less so than the more ancient ashes of Cader Idris and Aran Mowddwy. Sometimes they seem pure, and sometimes intermixed with every possible percentage of other sediments, muddy, sandy, and calcareous. Sometimes they are scoriaceous, rough, and stony, and sometimes as smooth and compact as the most close-grained felspathic trap, having been formed by the consolidation of felspathic dust, blown out from the same volcanic sources that yielded the felspathic lavas. In other cases crystals of felspar are embedded in a felspathic base, forming a stratified porphyry. Where ordinary sedimentary matter predominates they are apt to be fossiliferous, and contain Bala species. To separate each variety according to its kind would perhaps be impossible on any scale of map, for not only are they interstratified in every possible variety, but they also merge into each other in the strike in the most capricious manner. It was as much as could be done on a one-inch scale to indicate the whole mass in the manner shown, on which the Lower Silurian base serves to mark its stratified origin, and the dottings of red, yellow, and blue represent its ashy, sandy, and calcareous intermixtures. Over considerable areas the mode of colouring might with equal propriety be reversed, and adopting red for a base, dots of purple, blue, and yellow might be placed on it to indicate other substances mingled with the purer felspathic ash; but, on the whole, the ordinary sediment predominating, the Silurian colour has been chosen as a base.

Between Tremadoc and Llyn Ogwen the ashes occur in four distinct patches, all formed of equivalent strata. One of these lies between Beddgelert and Llyn-y-Ddinas on the southern side of the river. On the east it is partly faulted against the Bala beds that underlie the felstone on which it rests. Another, lying partly in Nant-Gwynant, occupies an irregularly triangular trough, the narrower end of which occupies the hills that approach Llyn-y-Ddinas, while the broad end stretches east and west between Cribiau and Llyn Llydaw on the eastern flanks of Snowdon (fig. 30). A third lies on the summit of Moel Hebog; and the fourth forms the peak of Snowdon (figs. 30 and 31), and stretches east along Crib-goch and north to Twll-du above Llyn Idwal.

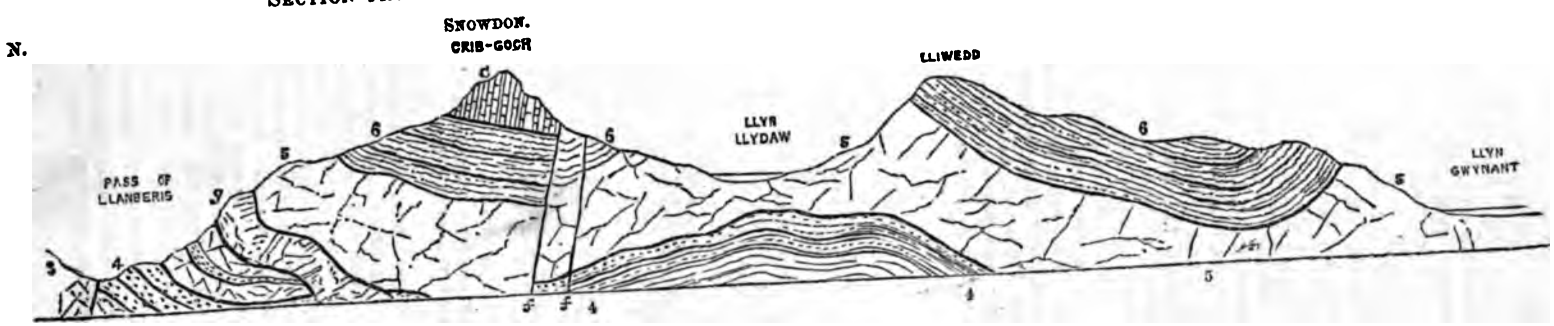
The rocks of Nant-Gwynant and Beddgelert possess forms of such extreme irregularity that I must refer to the map for their outline. They are contorted and faulted, some of the fractures being copper lodes, which have not generally been worked to much profit. At Llyn Gwynant the ashy beds and undulating felspathic trap dip north-west, and then rise in an opposite direction. The ash is well seen on the road for about a mile and a half north-east of the lake. Its bottom beds are there shaley, and contain a nodular felspathic band, above which are greenish, grey, and brown calcareous and sandy beds, on which there rests a brown calcareous breccia and conglomerate.

The following typical descriptions of the same rocks on the opposite side of the valley are partly derived from the note books of Mr. Selwyn. On the west shore of Llyn Gwynant "the beds dip north-west 45° to 50°, and are

* *See* p. 100. † *See* pp. 104 to 107.

Fig. 31.

SECTION FROM THE PASS OF LLANBERIS OVER CRIB-GOCH AND LLIWEDD TO LLYN GWYNANT.



3. Felspathic porphyries of Y-Glyder-fawr, dipping south-westerly.
4. Grit beds near Pont-y-gromlech.
5. Felspathic porphyry of Snowdon, Llyn Llydaw, and Llyn Gwynant.
6. Calcareo-felspathic ashes of Cwm-glas and Lliwedd.
c. Columnar-felspathic porphyry of Crib-goch. Outlier.
g. Greenstone.

" formed of soft greenish calcareous ash, which decomposes into a dark-brown " earthy rock. On the map, 260 yards north of the Y of Gwynant, they con- " sist of a hard grey calcareous rock, which weathers like the *Bala limestone*" in rough irregular cavernous lines. "This again becomes a soft gritty ash, " with nodules and angular fragments of good crystalline limestone. These " beds are somewhat similar to some of those near the top of Snowdon. A " little further westward, on Gallt-y-wenallt, there is a felspathic breccia and " vesicular ash, the vesicles being filled with carbonate of lime." This is the same breccia that we find on the east side of Nant-Gwynant, but between Llyn Gwynant and Gallt-y-wenallt it has become much harder and more felspathic, large blocks of felspathic porphyry being imbedded in a hard felspathic base. Between Llyn Gwynant and Llyn Llydaw the beds lie in an inclined synclinal curve in the manner shown in the diagram, fig. 31, where No. 6 represents the beds of brecciated scoriaceous ashes, and 5 the underlying slaggy-looking felspathic porphyry. The ashes and felspathic trap then roll across the valley to Crib-goch (above the Pass of Llanberis), where the ash is capped by several outlying patches of columnar felstone c.

The finest section of the ashes anywhere in Caernarvonshire is seen in the dark and lofty cliffs of Lliwedd that overhang Llyn Llydaw. There they consist of greenish grey calcareous beds, mingled with occasional felspathic breccias and conglomerates. They are sometimes fossiliferous, and the precise equivalents of the ashy rocks that form the peak of Snowdon* (fig. 30) and part of the serrated ridge of Crib-goch. On the crest of Lliwedd, two small isolated patches of compact blue felstone, equivalent to those of Crib-goch (fig. 31), rest on the beds of ash in the manner shown in the accompanying diagram by Mr. Selwyn.

Fig. 32.

PART OF THE CREST OF THE RIDGE OF LLIWEDD, SNOWDON, SOUTH OF LLYN LLYDAW.

W. E.

1. Felspathic porphyry.
2. Volcanic ashes of various kinds.
3. Compact blue felspathic trap.

The curves of these rocks are well seen from the miner's path on the north side of Cwm Dyli, and with a favourable light a good eye can easily follow the flowing sweep of the massive beds, and the outliers that rest on them and partake of their curvatures. These outliers are equivalents of the upper felstone of Gallt-y-wenallt and Crib-goch (figs. 30 and 31).

The natural boundary between ash and felstone south-west of Llyn Gwynant nearly coincides with the run of the turnpike road as far as Llyn-y-Ddinas, south of which the ashes abut on the porphyry of Moel-y-diniewed and Mynydd Nant-y-mor, in consequence of a fault which throws them down on the east. Part of the section No. 3, pl. 28, crosses the road about half-way between Llyn-y-Ddinas and Pen-y-bryn.† Immediately west of the road to Hafod-y-

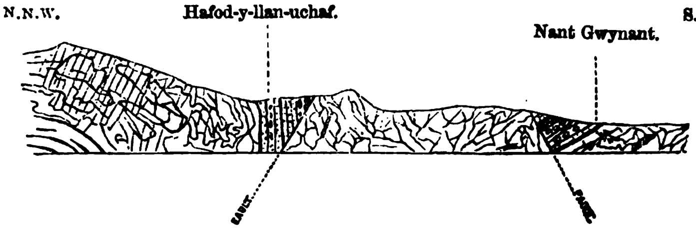
* Pl. 28, No. 3, and 6-inch section, Sheet 28, line 2.

† *See also* 6-inch section, Sheet 28, line 4.

llan-isaf, a triangular patch of the underlying porphyry appears at the surface. It is bounded by ash, and entirely enclosed by faults, which are respectively downthrows on the south, east, and north-west. Their throw is uncertain, but if the trap be of about the same thickness that it is on Snowdon, and if where the section crosses little besides the ashy beds have been denuded from its surface, then the eastern downthrow may amount to 600 or even 800 feet. That on the north-west is more remarkable, for vertical beds of ash stand on end upon the porphyry east of Hafod-y-llan-uchaf. (*See* section No. 3, pl. 28). On the west the underlying porphyry rises vertically, and immediately after, bending to the north-west, it sweeps along Cwm-y-llan towards the peak of Snowdon. The disposition of the rocks, as drawn in the section and in the following diagram, may appear improbable to those unaccustomed

Fig. 33.

SECTION ACROSS NANT GWYNANT, BETWEEN LLYN GWYNANT AND LLYN-Y-DDINAS.

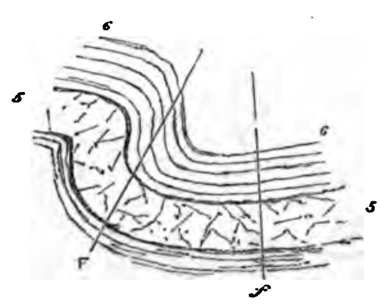


4. Fossiliferous grits.
5. Felspathic porphyry.
6. Felspathic ashes, calcareous.

to the extraordinary positions into which rocks have often been thrown in highly disturbed districts; and at first it is difficult to understand how the lower edges of the vertical strata should abut on the faulted edge of the porphyry, which in its natural position should lie horizontally under the ash. The origin of this arrangement may be explained as follows.

Suppose the masses of rock to have been curved in the manner shown in the following diagram :—

Fig. 34.



Let 5 represent the porphyry, and 6 the ashy beds; then in the line of the fault *f* (supposed to represent the Nant Gwynant fault) let the beds be thrown down about 600 or 800 feet on the side marked S.S.E., and let those on the N.N.W. side slip down about 1,800 feet along the line F (the Hafod-y-llan-uchaf fault), the result would be that some of the beds of the ashy rocks would rest on their ends on the porphyry No. 5, and this would be the case weather

the faults were formed in consequence of the bending of the rocks or after the curvatures had been effected. Then the whole being denuded, the rocks assumed their existing surface arrangement.

Between the vertical rocks at Hafod-y-llan-uchaf and the top of Snowdon certain broad curves again bring in the ashes where the peak of Pen Wyddfa* shoots into the air. The dotted lines in plate No. 28, section 3, show the denudation that these beds have suffered over part of this area, so as to separate the ash of Snowdon and Nant Gwynant. It is probable also that they were once covered by a great thickness of Bala beds higher in the series. The trough-like curve is well shown in the section, in spite of the fault that on the west of Snowdon causes the ash to abut against the porphyry in the neighbourhood of Llyn-du'r-Arddu, and the still more serious breaks that lie between Cynicht and the peak of Snowdon. The highest peak in Wales thus lies in the centre of an irregular trough, the sides of which have been broken by faults, and vast masses of the strata have everywhere been removed by denudation.

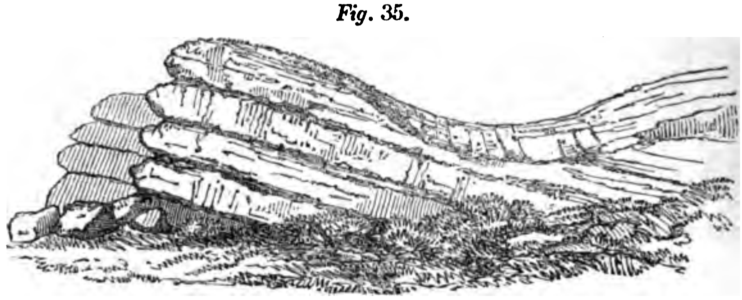
From the top of Snowdon the ash extends midway down the crags to the heights between Llyn Teyrn and the top of the Pass of Llanberis. From thence, much faulted, its lower boundary sweeps along the rocky ground between Crib-goch and the Pass not far below the pools that lie in the upland valley of Cwm-glas, and passing along the eastern and southern sides of Cwm-glas-bach, it strikes across the valley less than a quarter of a mile above the turnpike gate. From thence it skirts the west side of Esgair-felen to Twll-du (above Llyn Idwal), where it curves round to the south-west, and crossing the road near Cwm Patric, trends by Llechog to Llyn-du'r-Arddu, near which the ashes are crossed by the section.†

On the south side of Crib-goch, the strata are partly composed of dark brown ashes and volcanic sand or of slaggy-looking lapilli mingled with scoriaceous fragments. Above Llyn Llydaw it is often highly calcareous and irregularly bedded, these qualities inducing a rough cavernous outline in the decomposing outcrop of the beds.

The sandy and calcareous character of some of these beds is especially marked to the westward of Peny-lan, between Llyn Teyrn and Gorphwysfa. It there decomposes into a brown earthy soil, like that near the north end of Llyn Gwynant, and the area of this variety is easily distinguishable by the freshness of its verdure. Characteristic sections occur on the north side of Crib-goch, almost equal to those that overhang Cwm Dyli.

In Cwm-glas the same kind of phenomena are well shown. Below the pools in that valley there is a steep descent formed of felspathic porphyry and greenstone, overlooking the Pass of Llanberis. The ashy lines (which may be followed by the eye even from the bottom of the Pass) crown this cliff, curving in sweeping undulations, and being often bare of vegetation, the brown weathered edges of the strata are strongly apparent.‡

Fig. 35.



* "The Conspicuous Head," the Welsh name for the top of Snowdon.

† Sheet 28, and plate 28, No. 3.

‡ The surfaces of the rocks are here and in numerous other places beautifully polished and grooved by the ancient glaciers of Snowdon. (See "The Old Glaciers of North Wales," Ramsay.)

They are highly fossiliferous, yielding numerous casts of a large-ribbed *Orthis.*

Four triangular patches of felspathic porphyry overlie the ashes on Crib-goch. Three of these form the greater part of the crest of the ridge, and the fourth lies on its south slope. All of them occupy the same geological position as the patches of Lliwedd (fig. 32) and Gallt-y-wenallt, already mentioned, the whole having originally belonged to one broad mass that spread itself above the ashes, at least as far as Moel Hebog. On Crib-goch, two of them are each nearly half a mile in length, and the third, which lies between the others, is so small that it is scarcely distinguishable on the map. They lie in their present positions partly by the curvature of the strata and partly by complicated faults (fig. 31), which, in two instances, bring in juxtaposition the porphyries that lie above and below the ashes, once north of Glas-lyn by an east and west fault, and again, by a north and south dislocation, at the east end of Crib-goch. In both cases the throw cannot be less than from 1,000 to 1,200 feet.

Unlike the slaggy-looking porphyry that underlies the ash, the overlying trap is very compact and often columnar. When narrowly examined, the columns are not always very symmetrical, being generally four, five, and six sided prisms, from 3 to 8 inches in diameter. The rock is full of joints, and its fresh surface is greyish blue. It rings under the hammer, and by disintegration breaks up with a sharp and flinty fracture, apt to cut the shoes and hands of him who scrambles along the serrated ridge or across the steep and shingly slopes that surround the sharp peak at the eastern end of Crib-goch.

In these Cwms, rather than in the more accessible footpaths, the sections of this country can be best studied. Accordingly, on the path from Snowdon to Llanberis, the ashes by no means present themselves in their most typical form, being more calcareous, slaty, and sandy than ashy in texture, and containing here and there numerous fossils. *Orthis flabellulum* is plentiful, and in smaller quantity *O. Actoniæ* and *Latiopsis striatella.* The cleaved slaty structure is well seen at the summit of the mountain. Passing towards Llyn-du'r-Arddu, they become more felspathic. Between Cwm-y-llan, near the peak, and Llyn du'r-Arddu, the ashy beds dip north-westerly with gentle undulations at an average angle of about 5°, which on the cliff above the greenstone by Llyn-du'r-Arddu suddenly increases to 45°. These curves can easily be followed with the eye from the path that leads to Capel Curig.*

Pass of Llanberis, Twll-du, &c.—On the north side of Snowdon, between Cyrn-las and Cwm-glas-bach, the country is exceedingly craggy, and the felspathic porphyry and ashes so much resemble each other that in mapping it is impossible to separate them without hammering along every yard of the line. The same is the case above Glas-lyn. Both ash and felstone are porphyritic and weather grey; but the ribboned slaggy structure of one, and the bedded nature of the other, become apparent when rigidly looked for, and above the Pass of Llanberis it is found that, after many minor undulations, trap and overlying ash dip westerly and rise again in a sharp synclinal curve in the picturesque cliffs of Llechog. This curve becomes more narrow as it approaches the Pass opposite Cwm Patric, but it again widens and curves round in a basin-form above Llyn Idwal at Twll-du. Near the bottom of Cwm Patric the ash is calcareous, and decomposes into a soft brown sandy earth; and above Twll-du it is chiefly a kind of felspathic slate, accompanied by a rubbly felspathic vesicular conglomerate, which forms the greater part of the broken ground in the upland valley above Twll-du.† In the more slaty varieties numerous fossils are found, characteristic of the Bala limestone, of which it is the representative. The following species are from the lists of Mr. Salter, made on

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* The serrated outline shown in the section (Sheet 28, and pl. 28, fig. 3) are the consequence of the line on which the section was run across several of the minor ravines that run from the ridge towards Glas-lyn. The construction of such a section is a matter of considerable difficulty. Every foot of the line was chained, and the angles of the ground taken with the theodolite straight across the country, some of the ground traversed inclining at angles of 40° to 60°.

† *See* Plate No. 2, and 6-inch sections, Sheet 31, line 2, between Y-Glyder-fawr and Y-Garn.

the spot:—*Calymene brevicapitata, Cybele verrucosa, Trinucleus concentricus, Homalonotus bisulcatus, Lichas laxatus, Bellerophon carinatus, Holopella, Lituites, Orthoceras, Trochilites planorbiformis, Murchisonia scalaris, Ctenodonta, Orthis elegantula, Leptæna depressa, Orbicula, Tentaculites annulatus,* and *Favosites fibrosa.*

Such is a description, necessarily tedious when minute, of the ashy strata of Snowdon and Twll-du. The isolated patch that extends from Braich-y-Cornel over the summit of Moel Hebog to Moel Lefn resembles them. On Moel Hebog they lie in an inclined synclinal trough, and consist of the usual sandy, calcareous, and felspathic beds, in some places, especially near the base, brecciated or conglomeratic, and here fossiliferous. At Moel-yr-ogof the ashes are capped by two outliers of the same felspathic columnar trap that tips the ash of Lliwedd and Crib-goch. The disposition of the whole will be understood by reference to the following Diagram from a drawing by Mr. Selwyn, who mapped this part of the country.

Fig. 36.

MOEL-YR-OGOF ON THE NORTH FLANK OF MOEL HEBOG.

1. Fossiliferous grits and slates equivalent to those of Yr Arddu (Dolwyddelan) and Cerrig-Cochion.
2. Felstone porphyry (slaggy looking).
3. Felspathic, brecciated, and calcareous ash, equivalent to the ashes of Snowdon, Dolwyddelan, and the Bala limestone.
4. Upper columnar felspathic trap.
5. Greenstone.

CHAPTER XVIII.

THE SNOWDON AREA CONTINUED.

General Description.—Porphyries.—The volcanic ashes described in last chapter are underlaid by vast masses of felspathic rocks sometimes porphyritic, sometimes scoriaceous looking, sometimes what has been termed *slaggy*, the lines of viscous flowing being as apparent as in the cooled slags of an iron furnace. The base of this rock is highly felspathic, and it often contains small isolated crystals of felspar. Its fresh fracture is blue or grey, and it weathers white or cream colour. The slates or grits on which the porphyries rest are altered at the lines of contact, generally only for a few inches,

as may be seen at Cribiau above Llyniau-Duwaunedd, near Moel Siabod. The ashy beds above are quite unaltered, and this —and the perfect manner in which with the stratified rocks, the porphyry has been affected by all the contortions of the rocks of the country—proves that it is a great bed or set of beds of felspathic lava *interbedded* with fossiliferous strata. In no sense are the felspathic porphyries of Snowdon the cause of the disturbance of the rocks of the country, for, long after cooling, they have been themselves affected by these disturbances.

Nant Gwynant.—East of Nant Gwynant, and north and south of the point crossed by the section (No. 3, pl. 28), fossiliferous slates and grits already mentioned dip under the porphyry of Cerrig-Cochion and Cribiau (fig. 30), which at its base is somewhat brecciated, as if its under surface had cooled rapidly, while in the act of flowing, and the lava had broken up into scoriaceous fragments, cemented by inflows of melted matter subsequently cooled. The slate on which the trap immediately rests is so highly altered that for a breadth of about a foot it is impossible to define their limits. South-west of Cerrig-Cochion, on the hills east of Nant Gwynant, the trap stretches towards Beddgelert with a very irregular and faulted outline. It is of this part of the porphyry that the felstone rocks of Castell and Yr-Arddu are outliers* 6-inch Sheet, Section 28, and No. 3, pl. 28). They lie in well-curved troughs, and around and under them lie slates and greenish grey grits, containing Encrinite rings and many other Bala fossils. These are the precise equivalents of the sandy beds under the igneous rocks of Dolwyddelan, and just as in the country between that valley and Manod-mawr the sandy beds form the higher part of the series, so between Moelwyn and Yr-Arddu the beds are slaty below and sandy and fossiliferous above, their entire thickness, exclusive of injected greenstones, being about 6,000 feet.

West of Castell and Yr-Arddu the grits and slates dip E.S.E. from 20° to 40° as far as the jagged faults that bound the porphyry on the east from Bryn Gwynant near the lake to the neighbourhood of Pont Aberglaslyn. These faults cause the felstones to abut on slaty beds from 3,000 to 4,000 feet below those on which the same rock rests at Hafodydd-brithion,† Castell, and Yr-Arddu. Further south, about a mile east and south-east of Beddgelert, one of the faults must have even a larger downthrow (5,000 feet?), for all the felspar porphyry is cut out, and the ashes are brought into contact with the slates below the trap. This fault, also in part a copper lode, extends from Llyn-y-Ddinas to the hills about half a mile S.S.W. of Pont Aberglaslyn, where the felstone again abuts on the slaty and gritty beds below. Where the fault ceases the fossiliferous grits appear as far south as Y-Gelli-llydan, and the boundary line then passes west to Moel-ddu, and suddenly changing, strikes a little east of north by Beddgelert and Yr-Aran to the very top of Cwm-y-llan immediately under the peak of Snowdon. Except near Moel-ddu, the whole of this boundary, from Beddgelert to Yr-Aran, about 6 miles in length, is a fault, the porphyry being thrown down on the east against the blue slaty beds of Y-Graig-wen and Yr-Aran in the manner shown in Diagram No. 46. An unfaulted boundary line between the felstone porphyry and grits and slates then passes south-westerly across the ridge that unites Snowdon and Yr-Aran to the neighbourhood of Cae'r-lloi on the Caernarvon and Beddgelert road, and from thence passes southward to Moel Hebog. Along this part of the boundary the rocks are associated with lines of intrusive greenstone. From the top of Cwm-y-llan to the east side of Moel Hebog fossiliferous rocks dip north-west and west under the porphyry; and between that part of the igneous rock that runs from Moel-ddu‡ to Snowdon, and from Snowdon to Moel-Hebog, the rocks lie

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* Six-inch section, Sheet 28, line 3.

† About 2 miles east of Llyn y-Ddinas.

‡ 3½ miles N.N.E. of Tremadoc.

in the form of an anticlinal curve, the east side of which has been partly cut off by the Beddgelert and Cwm-y-llan fault.

The masses of rock, however, immediately rise in a synclinal curve, which (as the ground sinks on the south side of Moel Hebog) causes the felstone porphyry capped with ash to curve rapidly round at Braich-y-Cornel. From thence the lower boundary line strikes about 4 miles due north with an eastern dip, underlaid by fossiliferous grits, and afterwards runs north-east to Clogwyn-du'r-Arddu, on the west flank of Snowdon, where, for the present, I shall leave the line.

Moel Hebog.—The disposition of the rocks on Moel Hebog has already been shown in Diagram No. 36. The felspathic porphyry of that mountain and of Y-Graig-ddu are of the usual type, and frequently possess that slaggy structure of twisted and straight lines that indicate the curving and stretching of lava in lines of viscous flowing.* The crags of Y-Graig-ddu are intersected by patches of branching greenstones. North-east of this hill the ground is for a space covered by deep boulder drift, which from the bottom of the valley rises in long slopes up the sides of Yr-Aran and Y-Graig-wen. Rocky bosses, however, here and there project from the rubbish, sufficient to warrant the inference of the continuity of the rocks between Y-Graig-ddu and the broken country west of Cwm-craigog.

Snowdon.—On the ridge of Llechog, west of the peak of Snowdon, the felspathic porphyry is curiously cleaved, or at least very closely jointed; and so marked is this above Cwm-y-Clogwyn that it is difficult at first to believe that it is part of the very same slaggy-looking masses previously described. So completely is the appearance of the felstone of Llechog, and of the cliff below the peak of Snowdon, modified by this structure, that there is the utmost difficulty in fixing on a boundary line between it and the overlying ash, both being felspathic and both cleaved.

Fig. 37.

PEAK OF SNOWDON, CLEAVED ASH AND FELSPATHIC PORPHYRY.

1. Ashy beds. 2. Felspathic trap.

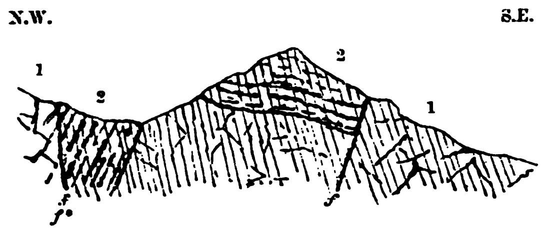
It is difficult to recognize the probability of intense cleavage being induced in a rock that has been melted, accustomed as we are to consider that cleavage of this nature is confined to stratified rocks. Less than 2 miles from this point, on the sides of Cwm-y-llan near Yr-Aran, the same structure is remarkable, and it was not till after repeated visits and much study on the spot, that Mr. Selwyn was enabled to draw the lines of demarcation between the ashes and the felspathic porphyry.

Looking south the arrangement of the rocks on Geuallt is explained in the following diagram by Mr. Selwyn.

* *See* p. 123. Between Snowdon and Llyn-y-gader.

Fig. 38.

SECTION SOUTH, ACROSS PART OF GEUALLT.



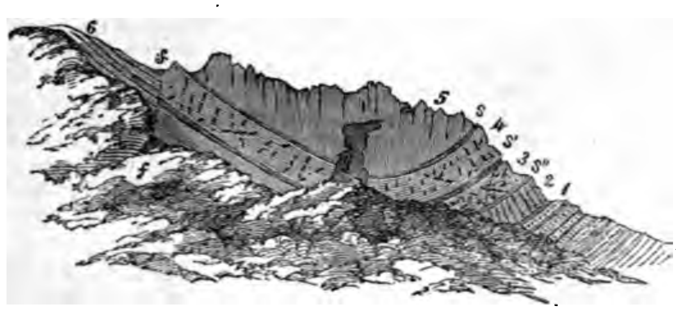
No. 1, on the east, represents the lower felspathic porphyry of the triangularly faulted area, about a mile south-west of Llyn-Gwynant.

No. 2, the felspathic ash faulted against this trap and rising to the west caps the trap, which here appears on the surface for about half a mile. The ashy beds 2 are then suddenly thrown in on the west by a rapid curve of the strata, and dipping westerly at a high angle they abut again on the same felspathic trap 1, in consequence of a fault (also a lode) which strikes from Cwm-y-llan S.S.W. across Geuallt and ends at a little fault about a mile north of Beddgelert.

I shall now resume the description of the north-west side of Snowdon, at Clogwyn-du'r-Arddu, where the structure of the porphyry may be advantageously studied from Llanberis. North-west of the peak of Snowdon, the felspathic porphyry breaks up into four distinct beds separated by slaty bands, symptoms of which may be less distinctly observed in Cwm-y-Clogwyn, where certain hard grits are interbedded with the felstones, but on too small a scale to be noticed on a 1-inch map. Together they lie in a synclinal curve between Bwlch-cwm-Brwynog and the cliffs above the south-east angle of the dark little tarn of Llyn-du'r-Arddu, where they are cut off by the fault *f* of the following diagram, and the ashy beds 6 that form the summit of Snowdon are thrown against them.

Fig. 39.

SYNCLINAL CURVE OF CLOGWYN-DU'R-ARDDU, SNOWDON.



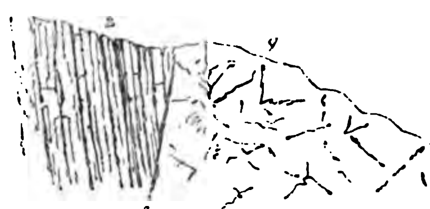
1. Gritty and slaty beds.
2 to 5. Felspathic rocks.
6. Felspathic ashy beds.
g. Greenstone.
s. Slaty beds.

Nos. 5 and 4 represent the chief parts of the masses of porphyry that underlie the ashy beds. They are here partly columnar, and the columns are generally perpendicular to the dip of its surfaces. Tortuous lines of viscous flowing, giving the rock, when closely examined, a slaggy aspect, are here strongly marked (fig. 42). On the whole these wave in the direction of the dip. No. 3

is a coarse felspathic breccia, No. 2 a compact felspathic rock rudely columnar, and between each there are thin beds of slate, marked *s*.

The slaty beds *beneath* all of these rocks are much indurated, adhering firmly to them at the junctions; and occasionally for a thickness of 2½ feet they look as if they had been almost fused by the melted matter that flowed across them when they formed the muddy bottom of the Silurian Sea. They are in some places scarcely visible from below, but a good climber who wishes to study the effects of the porphyry on the slate may here and there follow one along the synclinal line till it is cut off by the fault near the summit of the cliff. They generally form the merest lines of separation. Beneath the lowest bed lie the same sandy and slaty beds (No. 1) that underlie the felspathic porphyry of all the area already described from Moel Hebog to Dolwyddelan. A greenstone dyke (*g*) pierces these rocks, probably connected with the round boss that borders the lake and forms part of the cliff above. It is largely crystalline. Some minor faults occur in it and the ash that it pierces, one of which is a poor copper lode. Slate standing vertically, and probably brought there by the injected vein, occurs in the line of fracture. Passing into the body of the ridge of Clogwyn-du'r-Arddu, the same greenstone reappears in Cwm-y-Clogwyn, on the south side of the ridge.

Fig. 40.

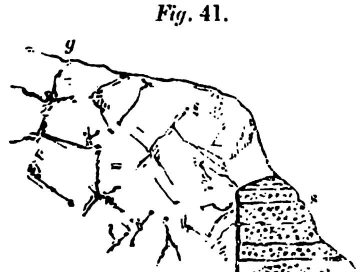


g. Greenstone. 2. Felspathic porphyry. *f*. Fault.

For a certain distance the felstone is brought against it by a continuation of the Llyn-du'r-Arddu fault *f*. On the cliff south of Llyn-y-nadroedd both stand in a vertical position, the felspathic porphyry being intensely jointed and perhaps cleaved.

The greenstone here consists of felspar and hornblende in about equal proportions, though occasionally felspar predominates. South of Llechog it widens out and branches, one arm running through the felstone near the Beddgelert path, and the other striking in among the strata of slate sandstone and conglomerate that underlie the felstone near Llyn-y-Gader, Y-Craig-ddu and Moel Lefn, north of Moel Hebog. Though it here follows the general strike of the strata for several miles, forming in part of its course a long rocky escarpment on the moor between Llechog and the Caernarvon and Beddlegert road, its intrusive nature is proved beyond a doubt, not only by the large branchings already alluded to, but also by the manner it (*g*) cuts through some of the

Fig. 41.



minor grit beds (*s*) that west of Llyn-y-nadroedd are interstratified with the porphyry, and inseparable from it on so small a map.

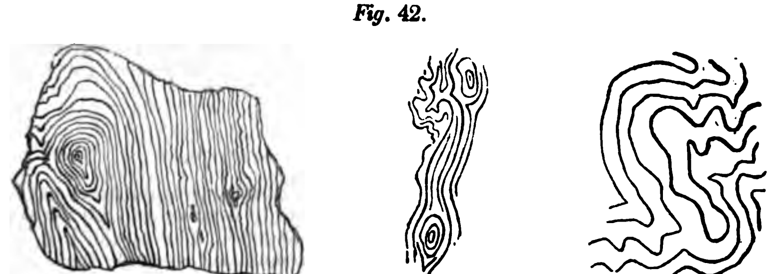
When intruded into the felstone the greenstone is readily distinguishable from it in consequence of its lighter hue, a peculiarity due to a covering of white lichens that generally flourish more luxuriantly on the softer greenstones than on the harder and more siliceous felstone rocks, so that after a time, partly by their tints, and partly by help of distinguishable varieties of outline the geological mapper can scarcely fail to observe, even at a distance, the presence of hornblendic rocks, though they may lie in the midst of the widely spread felspathic masses that form so much of the country.

From Clogwyn-du'r-Arddu the felspathic traps strike to the north-east, across the Pass of Llanberis, in three well-defined bands. The north and south fault that runs from Cwm-y-Clogwyn by Llyn-du'r-Arddu to Llechog (overlooking the Pass) appears to change rapidly in amount, and probably dies out before it reaches the Pass, though on Llechog, all the rocks being nearly vertical, this is necessarily uncertain. North-west of the peak of Snowdon the section (Pl. No. 28, Fig. 3)* crosses these rocks about midway between the summit of Llechog and Llyn-du'r-Arddu, and the position of the ash and porphyry is there partly inferred, but any one who considers the effect that such a fault must produce on dislocated masses of bedded rock passing by a rapid curve from a nearly vertical to a horizontal position, will admit the safety of the inference when studied on the ground.

The section at Llechog, like that of Clogwyn-du'r-Arddu, with a little clambering is easily accessible and peculiarly instructive, and were a geologist in doubt about the non-intrusive nature of the felspathic porphyries of Snowdon, there are no other places where he would be more likely to satisfy himself respecting their truly interbedded character, especially if he venture to follow the strike of the beds between the crags of Llechog, and Cwm Patric in the Pass of Llanberis. Throughout this course of less than a mile in length two well-marked thin slaty bands separate these beds of felspathic rock, and even from below with a favourable light, a good eye seizing the changing colours can follow them throughout. On the north-east side of the Pass, afterwards to be described, the slaty bands thicken and become more apparent.

On the summit of Llechog the uppermost mass of felstone crops out at an angle of from 70° to 80° dipping nearly east. The felspathic and calcareous ashes in immediate contact with it are very irregular in their dip, probably in consequence of the fault already mentioned. The porphyry is generally of a solid and massive character, and when weathered shows that wavy tortuous structure which I have denominated slaggy, and which I believe is in this rock due to the same cause that produces similar lines in some pitchstones, obsideans, pearlstones, and other non-crystalline recent lavas, or in the viscous flows that pass from iron furnaces in the form of slags. The accompanying drawings from large rocky fragments on Llechog, and at the base of Clogwyn-du'r-Arddu, show the nature of these lines.

Fig. 42.



* Also 6-inch sections, Sheet 18, line 2.

In a mere drawing it is difficult to distinguish these *seemingly* foliated structures from the foliations of gneiss and mica-schists. In the rock the difference is obvious. In gneissic rocks there is more or less complete separation of constituent minerals into layers consequent on metamorphic action subsequent to the original deposition of the strata. In the case of these traps it is a structure induced by original viscidity and rendered permanent by consolidation.

The mass from whence the blocks were derived is about 900 feet thick, and rests upon from 50 to 70 feet of sandy felspathic beds, somewhat slaty in structure, which in their turn lie upon nearly 500 feet of compact felspathic brecciated and conglomeratic rock (the continuation of No. 3 in the Llyn-du'r-Arddu section, Fig. 39), containing fragments similar in form to those shown in the following diagram:—

Fig. 43.

When freshly fractured the stony fragments are generally indistinguishable or faintly seen, but on weathered surfaces they become very apparent. Both matrix and pebbles are porphyritic, and from its general character, I incline to the supposition that much of the rock may have originally been a scoriaceous lava, the irregularly formed small fragments and larger blocks being mingled with fine ashy matter that fell on and among them, the whole having since consolidated into a compact mass. Sometimes also it looks as if loose scoriaceous fragments on the surface became entangled in the moving lava stream, and, retaining their form, became imbedded in it. The yellow felspar crystals in the matrix are generally of irregular form, and like those of most ashes are fragmentary. The probability that the above was really the mode of formation of part of this rock is increased by the circumstance, that in the continuation of the bed, and in the heart of Snowdon, there are no appearances similar to those now described, probably on account of the cooling having taken place under circumstances that did not admit of the formation of scoriæ.

The whole mass rests on about 100 feet of sandy rock, slightly mixed with ashy matter, which separates it from a bed of slaggy felstone 250 feet thick, similar in general aspect to that already described. This forms the lowest part of the igneous rocks of Snowdon, and it rests on beds of blue and brownish-grey grit and slate (equivalent to those of Moel Hebog and Dolwyddelan), beneath which are beds of blue slate, well seen along the ridge that overlooks the village of Llanberis.

Llanberis, Y-Glyder-fawr Llyn Ogwen, &c.

If we now follow the course of the Snowdon felspathic porphyries across the Pass of Llanberis, it appears that they strike steadily north-east to Llyn Idwal and Braich-du,* from whence they curve southward.† The lowest, striking southerly from the crags of Braich-du above Cwm-Lloer, recrosses the valley

* North of Llyn Ogwen.
† Maps 75 N.E. and 78 S.E.

by the bridge at the falls of the Ogwen, where the synclinal curve is uncommonly sharp, the rocks below the bridge dipping a little south of east about 80°, and rising again with a high westerly dip immediately above the waterfall. From this point the bed strikes south-east through Llyn Bochlwyd and over Y-Glyder-fawr to Llyn-y-Cwm-ffynnon, near the top of the Pass of Llanberis, where it thins out.* The bed of felstone above next curves round at Llyn Idwal, and, crossing the summit of Y-Glyder-fawr, descends to the Pass of Llanberis in that noble brecciated cliff from whence the massive ruins have fallen that give a name to Pont-y-gromlech.† From some points of view on the road, part of the broken crag stands out on the hill side like a huge tower, on which the great jointed gaps from whence the ruins fell are distinctly visible on the vertical cliff above. The third and highest curves round on the cliffs between Llyn Idwal and below Twll-du, and forms the shelving slope of Esgair-felen, and that magnificent crag that, seen from the lakes of Llanberis, rises above Cwm Patric from the left of the road.

From the upper part of the Pass of Llanberis the continuity of these felspathic lavas with that of Cribiau and Cerrig Cochion, is obvious, and this completes the circle of the felstone rocks that form the base of Snowdon, the description of which commenced when I showed its relation to that which underlies the ashes of Dolwyddelan.

Between Llyn Ogwen and the Pass of Llanberis various smaller beds of felstone appear and thin out. Two of these lie immediately south of Llyn Ogwen, one west of Llyn Bochlwyd, and others in and above the Pass of Llanberis west of Llyn-y-Cwm-ffynnon. The grits, that underlie the lowest felstone bed a little above the village in the Pass, increase in strength and importance as they approach Nant Francon and Llyn Ogwen, and the thin bands of slate interstratified with the felspathic rocks on Llechog thicken and pass into great masses of hard grit and arenaceous slate. They are strongly developed on either side of Llyn Ogwen, and at Llyn Bochlwyd, Llyn Idwal, and on both sides of Nant Francon below the falls, where they strike north up the cliffs of Craig-yr-hysfa, and south-west below the felstone of Y-Garn. As a whole, and especially in their lower part, they are the equivalents of the grits below the traps of Dolwyddelan, Cribiau, and Moel Hebog, and contain the same general assemblage of fossils with these, and with the beds that lie below the porphyries of Y-Tryfan.

The following diagram, fig. 2, Pl. 28, shows the relation of the rocks east and south-east of Llyn Ogwen to those of Snowdon, and also of a beautifully regular basin above Llyn Idwal in the high ground between the Pass of Llanberis and Llyn Ogwen.

On the south-east are fossiliferous hard grey felspathic grits, No. 4, overlying the felstones 3, that a little further north form the heights of Y-Glyder-fach and of Y-Tryfan.

Half-way up the broken slope the felspathic masses No. 3 roll over towards Y-Glyder-fawr in an anticlinal curve, the continuation of which further north, between Gallt-y-gogo and Y-Tryfan, is explained in Diagram No. 25. The upper part of No. 3 is a felspathic porphyry, occasionally brecciated on its upper surface, but generally of a compact slaggy structure, full of agate-formed concretions. The lower part is also porphyritic, and in the middle there lie about 300 feet of felspathic breccia and ashy-looking conglomerate. On the south-east side of the anticlinal the whole mass of trap is about 1,000 feet thick, and nearly 1,300 on the north-west side, and west of the synclinal of Twll-du and Llyn Idwal a part of it rises about a third of a mile west of Y-Garn in a band reduced in thickness, as shown by the dotted lines in the section underneath the level of the sea. The same fossiliferous grit and arenacenous slates (containing *Strophomena expansa*, &c.) that lie upon the trap in Nant-y-Gwryd roll over to the west (4) and are succeeded by the hard blue felspathic trap (5) (the lowest bed of the Snowdon

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* The rocks of Y-Glyder-fach, Carnedd Llewelyn, &c. are lower in the series.

† Or Cromlech Bridge, from the fancied resemblance to a Cromlech of the blocks fallen from the overhanging cliff. But there is no Cromlech there.

felstones) which, following the beautiful curve of the Twll-du synclinal, rises, reduced in thickness, on the peak of Y-Garn, where it is full of those small nodular agate-like concretions which are frequently so characteristic of the interbedded felstones of Caernarvonshire. The next, which forms the summit of Y-Glyder-fawr (5′), is about 1,000 feet in thickness, and is a continuation of the middle band of the Snowdon section (Fig. 33, Plate 28). The great felspathic lava beds, therefore, that run north from Llyn-y-Cwm-ffynnon by Glyder-fach, Y-Tryfan, Gallt-y-gogo and Carnedd Llewelyn to Conway, all lie in the Bala beds on a lower horizon than the felstone rocks of Snowdon. Bed No. 5′ is succeeded in ascending order by about 500 feet of arenaceous argillaceous slaty beds, containing two distinct local bands of felspathic ash. On these there rest about 300 feet of felspathic lava (5″), forming, in the Pass of Llanberis, part of the great shingly slope of Esgair felen. On its upper surface, near Llyn-y-Cwn, it is slightly scoriaceous and brecciated, and the whole curving round above Llyn Idwal rises on the west, and strikes with rather a stratified look across the Pass of Llanberis, and up the cliffs of Llechog, as the highest bed of the Snowdon porphyry, immediately beneath the calcareous ashes (No. 6).

Fossils.—The fossils of this district are as follows, in descending order:—

The fossils of this ash above Twll-du have been already given;* and in descending order the grits and slaty beds below the 5″ at the south end of Llyn Idwal contain the following species:—*Beyrichia complicata; Trinucleus concentricus; Bellerophon perturbatus; Orthis flabellulum*, and Encrinite stems. The next gritty bands below 5′ run from the east side of Y-Garn across the middle of Llyn Idwal, and up Braich-du across Nant Francon, thence bending round along the east slope of Y-Glyder-fawr, near the top, it strikes down to Pont-y-gromlech, and the west angle of Llyn-y-Cwm-ffynnon.† On the hills between this lake and Pont-y-gromlech, felspathic rocks (not shown in Fig. 2, Pl. 28), and the same fossiliferous grits, dip south-west at the angle of the slope of the hill under the great masses that form the slope of Snowdon in the Pass of Llanberis. The rock is concretionary, containing a number of agate-like nodules, somewhat chalcedonic, and the grits that rest on it sometimes convey the impression that the sediment had been spread on the surface of a scarcely cooled lava stream. On the north side of Llyn Ogwen the same grit widens out and forms the top of Braich-du, overlying the highest band of felstone on that side of the river. It contains *Strophomena expansa, Orthis flabellulum, Turbo crebristria, Murchisonia angulata, Orthoceras*, and Encrinites. Lower still the grits No. 4 below the felspathic lava of Y-Garn contain the same *Orthis* and *Strophomena* with the addition of *Leptæna sericea, Murchisonia scalaris, Scalites lenticularis, Rhynchonella*, and a *Fenestella;* and below this, interstratified with still lower igneous bands, above the Holyhead road on the cliffs of Craig-yr-hysfa,‡ the grits and arenaceous slates contain the same general assemblage of organic remains. As a whole they represent those grits just above and beneath the Capel Curig porphyries that surround Llyniau Mymbyr. Besides most of the fossils named above they also contain *Terebratula serrata* in vast quantities, and in smaller numbers *Mytilus, Lingula, Stenopora fibrosa*, and *Cornulites serpularius*, all species common to the Bala beds.

Greenstones.—I shall now explain in detail the mode of occurrence of the greenstone rocks on and around Snowdon.

These have heretofore only been incidentally alluded to. They are intrusive, and excepting a few narrow dykes, they are of Lower Silurian age. It is needless to describe each one; but a few of the principal masses may be specially noticed. All of them are hornblendic. Between Pen-y-gwryd and Cribiau § five patches pierce the stratified rocks and the overlying felspathic porphyry. They lie about the same level with those near Dolwyddelan and Moel Siabod,

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* P. 118.

† The syllable *lech* of Pont-y-gromlech lies in this patch, on the Map 75 S.E.

‡ Map 78 S.E., just above the Falls of the Ogwen.

§ Between the top of the Pass and Moel Siabod.

are dark green, and distinctly but not largely crystalline, hornblende predominating, and they alter the rocks with which they are in contact.

The line of greenstone about a mile in length that passes through Llyn-y-Cwm-ffynnon is well crystallized, slightly branching at its south-east end where the slaty rocks in contact with it are altered, and quarried for honestones. There are also several well-marked patches south of the Pass. One of these (*g*, Diagram, No. 31) branches at both ends into several ramifications. These are well shown in the large knoll (a true roche moutonnée) above Blaen-y-pennant, where the greenstone pierces the slaggy felspathic trap in all directions in thin veins, in some of which there is much quartz, like those that so frequently proceed from masses of granite. At its junction with the felspathic porphyry the greenstone is often partially decomposed; its crystalline character is gone (probably from rapid cooling at its sides) and it possesses a flaky structure to so great an extent, that it sometimes looks likes some of the cleaved decomposing dark green calcareous ashes, or in other cases assumes an appearance of a more slaty description. Another mass of greenstone beautifully crystalline breaks in among the rocks west and south of the twelfth milestone. A rock which makes honestones is in contact with it, originating probably in some short patch of slate associated with the felstone and altered by the greenstone.

A third boss about three-quarters of a mile across in all directions, forms most of the minor hills in Cwm Dyli and the hollow of Llyn Teyrn. The last is unusually felspathic for this district. Its well-marked columns may be seen from the Capel Curig path to Snowdon, near Llyn Llydaw, on an isolated hill that rises in Cwm Dyli, between Llyn Teyrn and the brook that flows from Llyn Llydaw.

Another short patch lies at the top of Cwm-y-llan, a little S.E. of the top of Snowdon. One of the long lines that stretch towards Moel Hebog west of Yr-Aran lies partly in the felstone and partly in the highest sandy part of the Bala beds that dip under the felspathic porphyries. Though intrusive, it dips like them north-westerly and rises again on the opposite side of the synclinal curve, in Cwm-y-clogwyn, where in two branches it lies, partly in the porphyry and partly in the underlying grits and slaty rocks north and south of Llyn-y-gader.

Fig. 44.

SECTION WEST OF YR ARAN, SNOWDON, LOOKING SOUTH.

E. W.

1. Slaty and grity beds.
2. Felspathic porphyry.
3. Greenstone.

Several other irregular bosses lie in the felstones of Y-Graig-ddu, north of Moel Hebog, which though very irregular in form and decidedly intrusive seem by signs known to the geologist to partake of the curvatures that have affected all the bedded rocks of this country, whether stratified or igneous.

North of the Pass of Llanberis there are several well-crystallized masses traversing the grits and felspathic porphyries; and a great vesicular, rubbly-looking patch forks across the rocks near the summit of Y-Glyder-fawr. A rock of similar character forms the top of Carnedd Llewelyn, and more massive in structure, rises like a great dark wall round the circular end of Cwm-llafar. These are not unlike the greenstone previously described,

that, on a lower geological horizon, forms the summit of Cader Idris.* One of the most striking bands begins on the hills less than 2 miles north-east of Llanberis church. It is partly columnar, and follows almost precisely the dip and strike of the slaty strata to Nant Francon, where crossing the valley, it ranges nearly in the same horizon up Craig-yr-hysfa, and curving round the edge of the north slope of Carnedd Dafydd, it strikes south to Afon Lloer, near Llyn Ogwen, still more or less agreeing with the strike and dip of the strata. Near the summit of Carnedd Dafydd it sends off a branch which, partly lying between the beds, trends south towards Llyn Ogwen, and the whole, though intrusive, clearly partakes of the synclinal curve, of which Braich-du is the centre. Seen only on the banks of Nant Francon along with another band a little further west, they might both easily be mistaken for true contemporaneously interbedded lava-flows.

The greenstones around Snowdon are perhaps all connected at no great depth beneath the surface by branching ramifications, but this is impossible to prove. They break out on different horizons in the Pass, in Cwm Dyli, Cwm-y-llan, Cwm-y-Clogwyn, and at Llyn-du'r-Arddu, yet, as already stated, they seem always to be affected by the curves into which the strata have been thrown subsequent to their intrusion; and it therefore seems probable, that like the great lines of greenstone between Llanberis and Ffestiniog and between Moelwyn and Nant Gwynant, their tendency has been to force their way in between the lines of bedding; but from causes difficult or impossible to trace, they have also branched underground hither and thither with considerable irregularity, and now when exposed by denudation, crop out apparently in a capricious manner.

Faults.—Some of the faults on either side of Nant Gwynant have already been described, and also those that run from the neighbourhood of Beddgelert to Llyn-y-ddinas and Yr-Aran (pp. 114, 115, 119, 121). It is scarcely necessary to enter into all the details of the effects produced by the faults drawn on the map of other parts of Snowdon; but as this is a district much visited it may be worth while to allude to a few of the more obvious. Where they most concentrate on the north-west of Glas-lyn several of them are copper lodes, one of which, generally striking to the north-west, and branching out in various directions, has been worked to advantage, and yielded a considerable supply of yellow sulphuret of copper. The long lines of white quartz, that like streaks of snow, contrast so strongly with the dark cliffs above the lakes, are all in lines of fracture, some of which are faults. Between Snowdon and Pen-y-lan there are nineteen dislocations, which, on such rough ground, it cost much labour to understand and map, and which are of importance, for they often throw the strata to be analysed up or down several hundreds of feet, and without them the true relations of the masses to each other would be unintelligible. One north-west fault passes from the hill above Llyn Teyrn towards the Pass of Llanberis. It is a downthrow on the west, and brings sandy and calcareous ashes against the *lower* felspathic porphyry. About half a mile west of this, in a direction a little west of south from the twelfth milestone, several faults dovetail beds of pure sandstone (belonging to the ashy series) into the same porphyry. Several east and west faults also considerably affect the country. One above the eastern half of Llyn Llydaw throws down brown sandy calcareous and scoriaceous ashes to the south, cutting out a considerable portion of them at the surface. Another, which passes along the south side of Crib-goch towards the copper lode, throws the *upper* columnar felstone down upon the ashy beds; and a third, which passes through Glas-lyn is a downthrow on the south, which in conjunction with a north-west fault that ends in Llyn Llydaw, lets in a small triangular piece of the same columnar trap on the southern slope of Crib-goch. A north and south fault passes along the steep slope of Crib-y-ddysgyl. It is a downthrow on the east, which above Glas-lyn brings the upper columnar trap against part of the ash, while on the west side of Cwm-glas the ash is thrown against the underlying porphyry that forms the great mass of Snowdon. Besides these there is the dislocation that runs north and south from Cwm-y-Clogwyn, through the east end of Llyn-du'r-Arddu to Llechog above Llanberis. This is a downthrow on the east, and though sufficiently

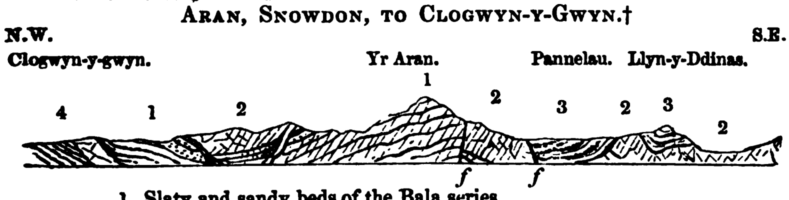
* See p. 28.

obvious where the rocks are inclined, where they become vertical on Llechog it necessarily becomes inappreciable. A branch of this fault, which cuts through the greenstone to the south-east, is a poor copper lode, and has occasionally been worked. The lower part of the Pass of Llanberis itself runs in a line of fracture, inappreciable when the beds are vertical (as between Cwm Patric and the village), but plain when the rocks are inclined or contorted lower down the Pass by the lakes.

Summary. — By help of the one-inch maps * and sections, especially that which crosses the peak of Snowdon (Pl. 28, No. 3), and of Fig. 30, it is not difficult to explain the order and relations of the masses of rock that form the mountain, and the heights and valleys in its neighbourhood. Slate and fossiliferous grits of the Bala beds lie at the base of the mountain; three great beds of felspathic porphyry (which southwards converge into one) lie upon these; still higher are beds of felspathic, sandy, and calcareous ashes; and highest of all are the relics of a sheet of felspathic lava, here and there perched on the ashes in outlying fragments, Figs. 31 and 32. The Snowdon section in the plate shows all of these but the last, and it also gives a good idea of the steepness of the mountain, and the sweeping though broken curves into which the beds have been thrown. One of these, under the north-east side of Cwm-y-llan, brings the sandy beds within a few hundred feet of the surface. A little further south the same denuded curve, faulted on the east, actually brings the slaty beds that lie beneath the porphyry up in the heights of Yr Aran. Before leaving the subject, I shall show the arrangement of the rocks on a line of section between Llyn-y-Ddinas, Yr Aran, and Clogwyn-y-gwyn, in the hope of clearing up any difficulty that may remain in understanding the structure of the country, especially the relation of the Nant Gwynant rocks, with those of Yr Aran and the ground east of Llyn Cwellyn.

Fig. 45.

SECTION FROM THE NORTHERN END OF LLYN-Y-DDINAS OVER YR ARAN, SNOWDON, TO CLOGWYN-Y-GWYN.†



1. Slaty and sandy beds of the Bala series.
2. Felspathic porphyritic lavas.
3. Calcareous and felspathic volcanic ashes = Bala limestone.
4. Greenstone.
f. Faults.

The great sheet of felspathic porphyry No. 2, lies on either side of Llyn-y-Ddinas, and rising in a steep escarpment on the north-west dips under wavy beds of the same ashy material (No. 3) that forms the peak of Snowdon. On Pannelau a tongue of trap 2 again rises in a sharp anticlinal, being overlaid

* 75 N.E. and 78 S.E.

† The south-east half of the diagram is from a sketch by Mr. Selwyn, the rest by myself.

on both sides by felspathic volcanic breccia and ashy slates (3). On the north-west side of the axis they dip in that direction with a waving line, and suddenly abut on the underlying trap 2, which is brought in by the Geuallt fault *f* already mentioned.* This fault is therefore a downthrow on the south-east.

The felstone is highly cleaved, the planes dipping W.N.W. about 70°. A little further, on the east side of Yr Aran, the line crosses the Cwm-y-llan and Beddgelert fault *f'*, also a downthrow on the east, of amount so considerable that the felspathic trap 2 is made to abut on grey and blue slaty and sandy beds No. 1, which in their natural position would be about 2,000 feet underneath the porphyry. The sharp peak of Yr Aran is formed of these strata dipping north-westerly from 20° to 35°. The planes of cleavage are inclined in the same direction about 50° or 60°, and slate quarries have been opened in the strata, which have proved of little value. West of Yr Aran fossiliferous slates and grits plunge under the long broad strip of felspathic trap 2 that unites Snowdon and Moel Hebog, and with a synclinal curve again rise on its western boundary, near Llyn-y-gader. They are associated with lines of greenstone 4, already described (fig. 44). This curve is part of the long bend that underlies the peaks of Moel Hebog and Snowdon, and of Braich-du, above Llyn Ogwen. On the west side of the upper end of Cwm-y-llan the dip of the rocks and the north termination of the greenstone may be seen on the cliffs, where it thins away in the manner shown in the following diagram by Mr. Selwyn.

Fig. 46

1. Slaty and sandy beds of the Bala series.
2. Felspathic trap, cleaved-looking, jointed, and columnar between the faults *f*, *f*.
3. Greenstone.
f. Faults.

The diagram, Fig. 45, when thoroughly worked out, ought to give a clear idea of ground on the south side of Snowdon that at first sight, on the spot, is not very intelligible. But, for a general understanding of the whole of the Snowdon section, any one with a good geological eye may grasp the entire order of succession during a walk up the Pass of Llanberis. First and lowest in the series, on the banks of the lakes are the Cambrian rocks, and above them the Lingula flags and Bala beds,† then come the felspathic porphyries and ashes that form the crest of the mountain. Let any one who wishes to get a clear idea of the great thickness of the igneous series of Snowdon stand between the turnpike gate and Pont-y-gromlech, and with a favourable light he may see on the right the great tiers of various rocks that, piled on each other, lie between the bottom of the Pass and the topmost peaks of Crib-goch, as shown in fig. 31. First,

* Three-quarters of a mile south-east of Yr Aran.
† *See* Section No. 3, pl. 28.

resting on beds of grit (4), there is the solid base of porphyritic and slaggy-looking felstones (5), here and there pierced by greenstones (*g*); and far up the mountain is a great black cliff, on the top of which thick beds of calcareous ashy rocks (6) undulate along in clear wavy lines that to the practised eye show a structure markedly different from that of the underlying massive rocks, or of the crags of columnar felspathic rock (*c*) that crown the ashes on the sharp ridge of Crib-goch.

At first sight it might be supposed that above Pont-y-gromlech the mass of the lower porphyry is far thicker than the same rocks lower down the Pass, on Llechog, since from the road looking up to Cwm-glas the felstone forms the great mass of the mountain. But this is partly deceptive, for the rocks, as drawn in Fig. 31, p. 113, are highly inclined on the southern side of the Pass, thus increasing their apparent mass, and the greenstone *g*, forming a sort of lofty wall, assumes an importance greater than its size would entitle it to in most other positions. Foreshortened from below, the slope looks as if almost inaccessible. Nevertheless, a ledge passes along its upper boundary, and the reversed dip (from 60° to 80°) of the intruded rock is shown in some places on the wall of felspathic porphyry that rises on the south side of the ledge. Seen on the spot, one cannot doubt that before its denudation the greenstone rose against this wall much above its present limits.*

The columnar trap *c*, of the diagram 30, is one of those isolated patches already frequently alluded to. The peak of Snowdon (Penwyddfa) barely escapes being capped by it. Always exhibiting the same sharp and columnar structure, and unconnected by dykes with any lower lying mass of igneous matter, it occurs in eight distinct patches, resting on the surface of the ash. Three of these are on Crib-goch, fig. 31, three on the opposite side of Llyn Llydaw on Lliwedd and Gallt-y-wenallt (diagrams Nos. 30 and 32), and two on the north slope of Moel Hebog (diagram No. 36), and one possibly above Twll-du west of Llyn-y-cwn; and I cannot doubt that the whole of the ashy beds were once covered by a sheet of felspathic lava, of which these small scattered patches are all that denudation has left to attest its former existence, perhaps on a scale as great as the porphyritic rocks that over an area of at least 60 square miles are known to underlie the ashes.

The thickness of all the igneous rocks on Snowdon may be estimated as follows:—

Columnar felspathic trap - -	200 to 300 feet.
Ashy beds - - -	1,200
Basement, slaggy and brecciated felspathic porphyries - -	1,700
	3,100 feet.

* This wall is several hundred feet above the Pass, and in some places it is polished and deeply and regularly grooved in an east and west direction by glacier action.

The whole easily divides itself into these three principal masses, but it is not therefore to be supposed that they are the result merely of three eruptions. Though under the greater part of Snowdon the lower porphyries coalesce and form one great mass, yet further north it has been shown to consist of at least three distinct lava-flows, interbedded with thick bands of fossiliferous grits and slates, indicating a long period of repose between the eruptions. It may have been that where the sheets coalesce the volcano for a space was elevated out of the water. Neither is it certain that each of the sheets was the effect of one flow. The 1,200 feet of ashy matter were clearly the result of gradual accumulation during intermitted eruptions; for while some of the beds consist of purely felspathic dust, mixed with broken crystals of felspar, and others are made of agglutinated cinder-like stones and lapilli, others are intermingled with every variety of common sedimentary sand, mud, and calcareous matter, with occasional bands of fossils that evidently lived and died on the spots where they were entombed. It is not even likely that all the ashy matter was directly showered through the air into the sea, but rather that much of it was recomposed, having first fallen on land around one or more volcanoes, from whence, mixed with ordinary sediments, it was spread abroad in the manner of other strata by the effects of marine denudation.

Whether the columnar trap above the ash was produced by the last eruption of the volcano that vomited the igneous rocks of Snowdon, or whether it was followed by other lava streams and beds of ashes, there is no way of discovering. On the left bank of the Conway (10 miles off), and in Merionethshire, above the horizon of the Bala limestone, all the rocks are formed of ordinary sediments without any volcanic admixture; and such as it is, this evidence would rather tend to show that the eruption that gave birth to the upper columnar trap of Snowdon was one of the last acts of the volcanoes of the area.

CHAPTER XIX.

The Lower Silurian Rocks of the Passes of Llanberis and Nant Francon, continued, and the Country between Llanberis, Criccieth, and Clynnog-fawr.

General Description.—Below the igneous rocks of Snowdon, and between that mountain and the Menai Straits, there lies a thick series of strata which, as a whole, nearly correspond to the Bala beds and Lingula flags that lie between Dolwyddelan and Traethmawr.

Fine sections of the Silurian strata are exposed in the high ridges on either side of Nant Francon and the Pass of Llanberis

the best being that on the south-west side of the Pass between the ridge of Llechog and the lakes.

With the exception of the fossiliferous sandy beds (described in last chapter) that immediately underlie the porphyries, the strata for three-quarters of a mile consist of dark blue and grey slate, dipping south-east from 60° to 80°, below which lie the grits and ferruginous slates of the Lingula flags. Rising from under these, at the upper end of Llyn Peris and in Nant Francon, are the unfossiliferous conglomerates, grits, and purple slates of the Cambrian series, in which lie the great slate quarries of Llanberis and Penrhyn. These are the equivalents of the rocks between Harlech, Trawsfynydd, and Barmouth. Beyond Nant Francon the same Cambrian and Silurian rocks trend to the north-east towards Aber and Conway, and south-west of the lakes of Llanberis they form the country to the shores of the bays of Caernarvon and Cardigan.

The interbedded porphyries and ashes of the Arans and Moelwyn in Merionethshire are, however, unrepresented in Caernarvonshire. If they existed their place in the series would lie somewhat above the Lingula grits that strike north from Llanberis along the ridge of Elidyr-fawr; but they have all thinned away deep under ground in the hollow of the trough between the igneous rocks of Moelwyn, and the western slopes of Moel Hebog Snowdon and Carnedd Llewelyn. Neither are the equivalents of the Tremadoc slates and Llandeilo beds certainly known in this quarter. If they exist in Caernarvonshire their place should be close above the Lingula grits of Elidyr-fawr. Either like the above mentioned igneous series they have thinned away in the trough, or they are unfossiliferous, or if fossils exist they are still to be discovered.

The great mass of felspathic porphyry of Llwyd-Mawr is a broad outlier of the Snowdon porphyry, and between Llwyd-Mawr and Moel Hebog the masses roll over in an anticlinal curve, fig. 49. Fossils seem to be rare in this area till we approach the country south of Moel Hebog. West of Llwyd-Mawr slaty Silurian strata dip south-east at a high angle, and no fossils have yet been found in them.

North-east of the Pass of Llanberis, as far as the country near Aber the Lingula and Cambrian grits, separated by slates of the Lingula flags, run in lines nearly parallel, dipping easterly from 45° to 70°. They form a marked feature in the physical structure of the country rising between Llanberis and Nant Francon in the bold ridges of Elidyr-fawr and Carnedd-filiast, Elidyr-fach and Bronllwyd. The same rocks trend from Llanberis south-west to the shore of Caernarvon Bay north of Yr Eifl.

Between Yr Eifl (or the Rivals) and Aber, various intrusive masses lie amid the Silurian rocks, the most remarkable of which form the mountain of Mynydd-Mawr by Llyn Cwellyn, Moel Perfedd and Bwlch Cywion on the west side of Nant Francon, and Y-Foel-fràs near Aber. A great mass of felspathic quartz-porphyry also lies among the Cambrian rocks between Llanllyfni and Bethesda, to be described in next chapter, and another near the shore stretches from Caernarvon to Bangor.

Llanberis and Nant Francon.—Everywhere in the Passes of Llanberis and Nant Francon the slaty rocks are so intensely cleaved that the bedding cannot be detected without rigid examination, especially since the bedding and cleavage nearly coincide. The strike varies from 30° to 45° north of east, and the rocks dip south-easterly about 80° and upwards. On the summit of the ridge, close to Y-Tryfan, Llanberis, the stratification is nearly vertical. (Section Pl. 28, No. 3.) On the slope, half-way down towards the Pass, a large gallery was excavated, in the hope that the quality of a certain vein of slate would improve in the body of the hill. When the geological lines were laid on the map it had been abandoned for years, but is now again in successful operation. In the Pass of Llanberis no fossils have been found in the beds between the sandy strata immediately below the felspathic porphyry and the Lingula flags, though cleavage and bedding nearly coinciding, there is no apparent reason why shells or their casts should be obliterated.

Between the Pass of Llanberis and Nant Francon the same slaty beds strike across the ridge of Foel-goch and Bwlch-y-breccan, and on the east side of Nant Francon, between Carnedd Llewelyn and the Lingula grits, the Bala beds are resolvable into two masses, separable by their colours. The lower and thicker part is light blue, and the higher part near the felstones is dark blue or almost black. Excellent sections occur a little further north on the sides of Cwm-llafar and Cwm-gaseg, and on the cliff of the latter valley below Yr-Elen the different coloured beds are exposed, abutting on each other on either side of the Llandbedr and Criccieth fault, which here throws the strata down on the east about 1,000 feet, in the manner shown in diagram No. 28. Beneath the fossiliferous grits of Carnedd Dafydd, the slaty part of the Bala beds seems almost unfossiliferous, for though frequently searched by Mr. Salter and myself, only one undeterminable graptolite was found. The same seems to hold good of the equivalent strata northwards to Aber and Penmaen-Mawr.

Lingula Beds.—Taking the Pass of Llanberis as a starting point, I shall now describe in more detail the Lingula flags between Clynnog-fawr and Aber.

Crossing Y-Tryfan* there is a fault about 30 miles in length, which runs from Llandbedr, near the vale of Conwy, to the sea near Criccieth. On Y-Tryfan it is marked by fractures filled with quartz, and the lower part of the overlying strata is thrown down on the east against hard quartzose Lingula grits, which dipping south-easterly are cut off by the fault before they reach the base of the hill. (Section 3, plate 28, and 6-inch sections, sheet 28, line 2.) On the opposite side of the Pass, the grits reappear immediately east of Llyn Peris, in a vertical or even slightly reversed position. Here in some minor fractures spots of greenstone occur, and the main fault forms the eastern boundary of the grits for about half a mile. Below them on either side of Llyn Peris are ferruginous slaty Lingula beds on end, about 1,000 feet in thickness, and resting on Cambrian grits. From the Pass, the Lingula grits trend a few degrees east of north, in the form of thick quartzose beds and conglomerates, interstratified with slaty bands. They dip easterly at high angles, and, being less easily denuded than the overlying and underlying slates, by their hardness they form the sharp ridge of Elidyr-fawr, on which they are about 1,300 feet thick. From the bottom of the Pass the beds in inclined tabular masses may be seen cropping distinctly out and ranging far up the mountain, on which great shivered blocks lie piled on each other in ruinous confusion, rendering the ascent unusually toilsome. At the north end of Elidyr-fawr the whole series may be observed bed by bed striking downwards into the hollow of Marchlyn-mawr, and dipping east at angles of about 70° and 80°. Towards their base they are somewhat slaty, but the main mass consists of grey and brown grits, occasionally conglomeratic, in which, near the base on the south margin of the lake, I found *Lingulella Davisii* and *Olenus micrurus*.†

A clear and characteristic section occurs on the hills overlooking Nant

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* On Snowdon, Map 78 S.E.

† It is worthy of remark as showing the uncertainty of discovering rare fossils, that when in 1848 I mapped these rocks this *Lingulella* and *Olenus* were knocked out at the first blow of the hammer, and though in this locality the beds have since been systematically examined for organic remains, both by myself and others, not a single additional fossil has rewarded the search. Between the base of the grits and the Cambrian rocks the slates are concealed by thick glacial drift.

Francon. Standing on the ridge of Carnedd-filiast, an immense bare shelving surface of rock, covered with large wave-like ripple or current marks, strikes the eye, dipping a little south of east about 36°, and forming a considerable portion of the higher part of the west side of Cwm-graianog. Further down numerous casts of *Cruziana semiplicata* and other great *annelide* tubes are common on the rippled surfaces, both in the rocks in place and on the large fragments that strew the centre of the valley, and form the symmetrical moraine across its mouth (Plate 3).

From below, looking south-west on the Holyhead road, above the 32nd milestone, the whole series is visible, striking in distinct beds from Moel-perfedd and Carnedd-filiast down to the large *roches moutonnées* on the bank of the river Ogwen. In the opposite direction for two miles they are also easily traceable across the hills by Bwlch-hela to Garth, where they are cut off by a fault (a downcast on the north-west) of about 2,000 feet, which seems to throw them against the Cambrian grits. Their precise relations are, however, obscure, owing to the thick drift that covers the valley of Afon-ffridd-lâs. *Lingulella Davisii* in great numbers was found in the grits near Tyddyn-du (Plate 2).

North and west of the fault the Lingula grits are distinctly traceable to Moel Wnion, and between that hill and Aber they are repeated in a singular manner by five faults, the nature of which will be described, p. 163. Along all this long strike from Llanberis northward, the grits are underlaid by about 800 or 1,000 feet of dark blue ferruginous slate, which separates the grey grits of the Lingula series from the underlying green and purple rocks of the Cambrian area. In this lower part of the Lingula beds no fossils have yet been found in this part of Caernarvonshire.

Between Llanberis and Llyn Cwellyn on the south-west* the Lingula grits, so prominent on Elidyr-fawr, generally lose their strongly defined character, partly because much of the ground in Maes cwm and Cwm Dwythwch is obscured by drift, heath, and peat, and perhaps also in part because the grits are *unconformably overlapped*, or that they thin away, or pass into slaty material. It is also not unlikely that as the strike of the country is here much disturbed, parts of the series may be cut out by undetected faults, probably continuations of some of those that so thickly intersect the hills overhanging Llyn Peris.

South of the valley of Llyn Cwellyn the relations to each other of the Silurian divisions is in places still obscure; but in the valley south of Mynydd-mawr the Lingula grits and slates are both well developed between Nant-y-llef and Llyn-y-dywarchen.

On the broken slopes on the south side of the valley, the beds form a dome-like anticlinal axis, the ends of which have been broken and cut off by faults. The eastern fault is probably a continuation of that which crosses Y-Tryfan, from whence, for the greater part of the way, it may be inferred by quartz fragments on the surface, but the rocks being of similar quality on both sides of the fault, it is impossible to prove any actual displacement. Between Llyn Cwellyn and Llyn-y-dywarchen the Lingula grits of Clogwyn-y-gareg dip north for about an eighth of a mile, and N.N.W. towards the fault and copper lode, where they are thrown against the overlying strata in the bottom of the valley. From thence the grits full of minor cracks may be traced westward to Tal-y-mignedd, where dipping at high angles to the north and west they curve southward on the western slope of the mountain, where they are cut off by an east and west fault which throws down the Bala beds against them on the south.

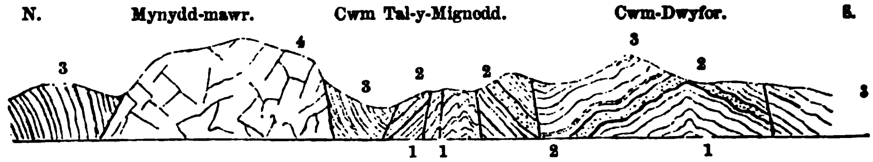
This fault crosses Cwm-y-ffynnon† about half a mile below the spring, and another strip of the same Lingula grits appears abutting against the fault, and dipping south-east on the southern side of the arch. It thus happens that the Lingula grits and the Bala beds on opposite sides of the fault are brought together, and this also happens between the west slope of Y-Garn and Clogwyn-gareg. The following diagram shows the arrangement of these strata on a north and south line drawn across Mynydd-mawr to Cwm-Dwyfor, a hollow the drainage of which forms the source of the stream that passes down the long valley bounded on the east and west by Moel Hebog and Llwyd-mawr.

* Map 78 S.E. and 75 N.E.

† Ffynnon signifies a well or spring.

Fig. 47.

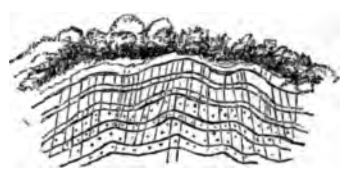
SECTION FROM MYNYDD-MAWR TO CWM-DWYFOR.



No. 1 represents the Lingula slates, and No. 2 the Lingula grits in Cwm Tal-y-mignedd, No. 3 the Bala slates, and No. 4 the great intrusive boss of Mynydd-mawr. The slate that underlies the grit is here much lighter in colour than that which overlies it; and several of the dislocations are good copper lodes.

The Lingula slates and grits rise in Cwm-Dwyfor, where, at the upper end of the valley, they may be seen bending in a wavy dome-like curve.

Fig. 48.



The overlying slate is here so much cleaved that but for the grits the stratification would be undistinguishable. Beyond the point of outcrop the grit slopes southward towards the bottom of the higher valley, but beyond the junction of the brooks it is probably covered up by the overlying slates and cut off by the fault that passes down the valley to Criccieth.

Llwyd-mawr, Moel Hebog, &c.—A little more than a mile south of Cwm-Dwyfor bands of grit again appear on the west side of the valley, and conglomerate occurs on the hills opposite Brynkir. All these are overlaid and underlaid by blue and black slate, and they are considerably faulted, the cracks sometimes containing a little copper ore and much iron pyrites. The whole dips westward at angles ranging from 20° to 60° beneath the felspathic porphyry of Llwyd-mawr, Fig. 46. The cleavage all along this side of the valley dips a few degrees north of east, at angles from 65° to 85°, and sometimes it is vertical. The slaty beds, though much obscured by drift, yet as a mass dip distinctly under the felspathic rock that forms the base of Moel Hebog. The rocks, in fact, between Llwyd-mawr and the west side of Moel Hebog form an anticlinal curve about 2 miles in width, and the igneous rocks that cap the slates on either side are equivalents (Fig. 48). At the top of the slates are fossiliferous sandy Bala beds that immediately underlie the porphyry of Moel Hebog, but between these rocks and the river there seems to be no Lingula flags, probably owing to the fault that passes down the valley, throwing them low on the east side of the anticlinal axis; and it is not till we approach the country between Dolbenmaen and Tremadoc that the sandy Lingula beds distinctly crop out in a broad curve, dipping north-east and north-west between Moel-y-gest and Ynys-cynhaiarn,* the details of which have been already given in Chapter IX.

Between Criccieth and Nant-y-llef there occurs the vast igneous mass of Llwyd-mawr, already alluded to, forming a wild mountain tract, about 7 miles in length, by about 3 in breadth. Its surface is rough, broken, and strewn with great blocks of porphyry; its northern end is intersected by valleys, the sides of which are high and precipitous. The rock consists of a compact, felspathic porphyry, blue in its fresh fracture, weathering pale yellow or white

sometimes wavy or "slaggy" in structure, and generally similar to the solid mass of felspathic porphyry that underlies the ashes of Snowdon and Moel Hebog. Mr. Selwyn, who mapped the ground round Moel Hebog and Llwyd-mawr, first proved that all this broad igneous tract forms but an outlying portion of the rocks of Moel Hebog (Fig. 49), and indeed, generally of the great lava sheets, that even in their denuded fragmentary condition extend from Carnedd Llewelyn above Nant Francon almost to the north shores of Cardigan Bay.

The western boundary of the Llwyd-mawr porphyry between Ynys-ddu and Pant-glas is obscured by drift. The rest of this line by Llyn-cwm-dulyn and Llyniau-cwm-silyn is well defined, the junction of slate and porphyry being almost visible on the cliffs above the lakes, where beds of altered porcelanic slate dip under it at high angles. Seen from the rocky pass of Cwm Trysgyl on the north flank of Moel Hebog, in a favourable light, an experienced eye can detect on the cliffs the general dip of the slaty beds of Mynydd-Tal-y-mignedd beneath the porphyry of the cwm above Craig-cwm-silyn. The structure of the country will be easily understood by reference to the following section from Moel Hebog to the north-west across Craig-cwm-silyn, a little to the south of Llyniau Nant-y-llef. It includes all the rocks from the quartz porphyry* and Cambrian strata to the ashy equivalent of the Bala limestone.

A glance at the map will show that the Lingula flags (Fig. 49) north-west of Craig-cwm-silyn are continuous in the line of strike with those of the Pass of Llanberis. The whole of these beds have a tendency here and there to become sandy and ferruginous, thus resembling the Lingula flags of Ffestiniog and Dolgelli. The grits south-west of Llyniau Nant-y-llef rest directly on Cambrian slates, but further west the boundary line is obscured

Fig. 49.

SECTION FROM THE QUARTZ-PORPHYRY NEAR LLYNIAU NANT-Y-LLEF, ACROSS LLWYD-MAWR, TO MOEL HEBOG.

p. Quartz porphyry, being a continuation of that of Llyn Padarn, Llanberis.*
1. Cambrian purple slaty rocks.
2. Probably Lingula grits.
3. Blue slaty rocks, in the higher part probably all of the Caradoc or Bala series.
4. Fossiliferous grits, equivalent to those under the Snowdon porphyry.
5. Felspathic porphyry of Craig-cwyn-silyn Llwyd-mawr, equivalent to that of Snowdon, Moel Hebog, Y-Glyder-fawr, &c.
6. Calcareous ashes and conglomerates, equivalent to those of the peak of Snowdon, Dolwyddelan, &c., and on the horizon of the Bala limestone.
f. Faults.

* A fuller description of the porphyry (*p*) and of the Cambrian strata is given at pp. 140, 142, 145, but in the meantime it may be stated that on the south and west, when not faulted against the porphyry, the Cambrian rocks are so excessively altered that it is often difficult to separate them from the intrusive igneous mass which has produced the alteration.

by drift. There is, however, little doubt that it passes out to sea about half a mile north of Clynnog-fawr, near Ty-coch. The reasons for this conclusion are, that on the north side of Mynydd Llanllyfni at Llwyd-coed there occurs the most southerly quarry of purple slate in the district (Map 75 N.W.), and between this point and Fridd-bach, when not obscured by drift, there are indications of purple slates on the north side of the line, and black slate on the south.

West of Fridd-bach no purple slate is seen, and it is probable that it is cut out by a fault which throws the Silurian strata against a low part of the Cambrian grits.

Intrusive Rocks.—The intrusive rocks associated with the Silurian strata described in this chapter are as follows, beginning from the south. There are several patches of greenstone in the valley north of Llanfihangel-y-Pennant, and others in Cwm-y-ffynnon. One of these, Craig-isallt, close to Llanfihangel-y-Pennant, forms a striking feature in the scenery. The peak of Y-Garn* consists of an igneous rock similar to that of Mynydd-mawr. The long strip that runs from the north cliff of Y-Garn towards Llyn Cwellyn is hornblendic greenstone.

The boss of Mynydd-mawr is one of the most beautiful rocks of this country, consisting of a felspathic base, when slightly weathered of a pale cream colour, in which small specks of hornblende are scattered, and very rarely minute granular crystals of quartz. If deeply quarried the colour of the base would probably be blue. The specks of hornblende render it unlike any of the great interbedded felspathic lavas which form so much of Snowdon and Moel Hebog. In the form of a great boss it rises through the slate which may be seen here and there in a porcelanized condition on its margin (fig. 47). An instance occurs on the slope towards Nant-y-llef where the igneous rock abuts on vertical planes which probably are lines of bedding, for, as in the case of the altered slate in contact with greenstone between Dolwyddelan and Ffestiniog,† it is unlikely that at Mynydd-mawr the porcelanized slate should have been cleaved after undergoing this species of alteration. The absolute junction is obscure at the base of the north cliff, but near it blue slate and grey arenaceous beds dip towards the tall cliff of Craig-cwm-bychan and Cwm-du, where the rock is largely jointed and somewhat columnar. On the south of the mountain great banks of shingle lie along the steep slope at the base of Craig-y-bera, concealing the absolute boundary, which nevertheless may be approximately inferred.

Nearly opposite the village of Llanberis three greenstone dykes pierce the slate on the hills between Llechog and Y-Tryfan, occasionalry breaking a little athwart the slate. (Pl. 28, section 3, and 6-inch sheet No. 28, line 2.) They are distinctly visible from the bottom of the Pass. The eastern dyke splits into two as it rises to the summit of the ridge, while the western dyke thins away at a lower level. Another broad well-crystallized dyke cuts the slaty rocks at Ty'n-y-ffynnon on the opposite side of the valley, and three others nearly in the same beds crop out near the summits of the ridge of Moel-y-cynghorion and Moel-goch on their northern slopes, between Llyn Cwellyn and Llanberis.

Fig. 50.

Moel-perfedd.

p. Felspathic porphyry.
l. Lingula beds.

* About 2 miles south of Llyn Cwellyn.

† Page 97.

On the west side of Nant Francon the igneous mass of Moel-perfedd rests in a singular manner on the Lingula grits of Carnedd-filiast. The base of the rock is felspathic and very sparingly speckled with hornblende. It is intrusive, and alters the rocks with which it is in contact, but instead of rising from below like a dyke or boss, it lies on the summit of the sharp ridge in the form of a large wedge, tapering downwards.

It is not easy to account for the occurrence of a rock of this kind in such a position. It does not seem to rise from below through a neck, but possibly before the rocks were thrown into their present inclined position it may have been injected among them in connexion with the larger and lower mass of porphyry of Llyn Padarn, the continuation having been removed by denudation.

A similar rock intruded among strata on a higher horizon forms the craggy hill between Blaen-y-Nant and Bwlch-y-Cywion. It resembles some of the granitic rocks in which free silica has not been fairly developed, and in the cliffs above the road and on the heights near Bwlch-y-Cywion small veins have been injected from the main mass among the slates, which at the junction are altered into porcelanite. The layers of slate look wavy at the junction, and quartz veins (not foliated) branch among them just as they often do at the ends of branching veins of granite. The same kind of phenomena are observable about 4 miles further north in the greenstone west of Yr-Elen. This rock sometimes approaches syenite in its structure, and on the south side of Cwm-Gaseg sends veins into the slate, which in its neighbourhood has a baked aspect, and is spotted like "snakestone," an appearance common in slates in contact with intrusive masses. On the east side of the greenstone the slate of Yr-Elen and Cwm-gaseg dips towards it at angles varying from 15° to 25°, and on the opposite side the same beds dip 10° S. of E. about 5°. The cleavage is vertical, and its strike in general coincides with that of the bedding. Beyond this is the great intrusive felspathic boss of Y-Foel-frâs.

CHAPTER XX.

The Cambrian Rocks of Caernarvonshire. Llanberis, Llyniau Nant-y-llef, &c.

General Description.—It has been already shown that the Cambrian rocks of Merionethshire and Caernarvonshire form the opposite and lowest beds of a great synclinal curve, the upper strata of which are Lower Silurian. Before entering on details I shall describe the general arrangement of the Cambrian strata, near the Menai Straits, between Aber on the north and Clynnog-fawr on the south.

On the south the boundary of Cambrian rocks and Lingula flags runs east from Caernarvon Bay to Mynydd Llanllyfni, from whence it strikes north-east through the lower lake of Nant-y-llef, and passes by Bettws Garmon and Dinas to Llyn Padarn, near Llanberis. Here the boundary line bends south-easterly, and, interrupted by several faults, the uppermost Cambrian rocks form the hills above Llyn Peris. From thence the same strata strike north-easterly along the ridge of Elidyr-fach and Bronllwyd to Nant Francon, overlooked by the sharp ridge of the Lingula grits of Elidyr-fawr. In Nant Francon the line crosses

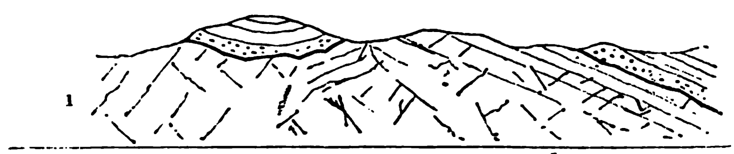
the Holyhead road (about 220 yards below the 31st milestone), and interrupted by a fault stretches towards Aber, about 2 miles from which the rocks roll over to the west in a broken anticlinal curve which is cut off on its western slope by the great fault that runs south-west from Aber to Dinas Dinlle, on the coast of Caernarvon Bay. This fault bounds the Cambrian rocks of Llanberis for about 14 miles, throwing down the Silurian slaty shales on the north-west against a low part of the Cambrian strata. From beneath them the Cambrian beds again crop out to the north-west, between Bangor and Llanddeiniolen. Both areas include large masses of quartz porphyry.

Between the quartz porphyry and the Lingula flags at Llanberis, the whole of the Cambrian rocks, in spite of certain sharp contortions, have an average south-easterly dip. In some degree they differ lithologically from the rocks of Merionethshire, for whereas the latter are almost entirely formed of grits, in Caernarvonshire great and valuable beds of slate are interstratified with grit and conglomerate. The cleavage strikes north-easterly with the strike of the beds, and is but little affected by minor contortions, being either vertical or dipping at very high angles south-easterly, in the direction of the average dip of the rocks of the country.

The best sections are in the Passes of Llanberis and Nant Francon, where the succession of the strata, as a whole, is as follows:—The highest beds consist of about 1,300 feet of green, greenish grey, and occasionally of purple hard grits, generally thick-bedded, and formed of grains of quartz often but little waterworn, intermingled with felspar grains in smaller proportion. Section No. 3, pl. 28, and figs. 43 and 54; (also 1-inch map 78 S.E., and 6-inch section, sheet No. 28.) A little copper pyrites has been occasionally worked in it near Llyn Peris. Beneath the grits rise the bluish purple and purple slates of the larger slate quarries of Penrhyn and Llanberis, and below these are other thinner bands of slate, grit, and conglomerate, the lowest of which, by Llyn Padarn and elsewhere, *passes into* the great mass of quartz-porphyry that for 13 miles strikes along the midst of the Cambrian strata, between Llanllyfni and St. Ann's chapel, on the river Ogwen. So closely does the matrix of the altered rock resemble the adjoining typical porphyry in colour, texture, and even in porphyritic character, and by such insensible gradations do they melt into each other, that the suspicion or rather the conviction constantly recurs to the mind that the solid porphyry itself is nothing but the result of the alteration of the stratified masses carried a stage further into the region of that kind of absolute fusion that in so many regions resulted in the formation of granites, syenites, and other rocks, commonly called intrusive. This conclusion is further aided by the capricious variation in thickness of the strata adjoining the porphyry,—as, for instance, in the case of the thin conglomerates of Llyn Padarn and Clegyr, which are the equivalents of the far thicker beds around Dinas Mawr, a little north-west of the lake. This I can only account for by the supposition that these beds have, as it were, been partly

eaten into by heat and themselves converted into porphyry. Further, the porphyry itself has in places a thick-bedded appearance, especially on Moel-gronw, where the lines are inclined in the direction of the dip of the neighbouring strata.

Fig. 51.



1. Porphyry. 2. Grit, conglomerate, and slate.
* Planes in porphyry, dipping in accordance with the dip of the adjoining strata.

Such appearances have often been explained (perhaps in some cases justly) by the hypothesis of the formation of planes of cooling supposed to coincide more or less with the lower surface of the strata that once covered underlying crystalline masses, but in this instance I believe rather that the lines indicate traces of stratification in a rock, the original felspathic and quartzose material of which has been metamorphosed into true porphyry.

Details of the Cambrian Rocks, Llanberis, &c.

I shall now describe the Cambrian strata of Llanberis and the county further south in detail. The minor stratigraphical relations are exceedingly intricate.

On the south side of the lakes, between Y-Tryfan and Dinas, the Snowdon section (Plate 28, No. 3, and 6-inch sheet No. 28), crosses the Cambrian grits, which lie in the form of faulted anticlinal and synclinal axes. These if unbroken would present a form for the top of the Cambrian strata somewhat like that given in the lowest dotted line on the plate. The faults are clearly connected with the contortion of this piece of country. A sharp curve in the strike has, as it were, been attempted between Llyn Peris and Dinas,—the hard rocks resisted the bend and fractured, and six large faults with repetitions of the grits are the consequence. It is the complication induced by these faults that apparently gives the Cambrian grit an undue importance along the southern shores of the lakes. Forming a mass of rugged hills and broken ground they appear far thicker than they actually are, and it requires much dissection of the strata to make out that the crags of Pen-carreg-y-fran, the vertical beds of Derwyn, and the inclined strata of Ceunant-mawr, are together all represented by the narrow strip of grit that crosses by the slate quarries from Llyn Peris to Nant Francon.

Below Dolbadarn the grits as it were escape from the fractured country, and curving to the south-west by Dinas they gradually thin away towards Bettws Garmon,* where they disappear.

North-west of Dinas the section of the Cambrian rocks is simpler than on the opposite side of the lakes, though at first the contrary might be supposed. The following is its descending order, as shown on the section. (No. 3, pl. 28, and 6-inch sections, sheet 28, line 1.) Dipping from 30° to 45° below the Lingula flags, No. 6, the upper grits of Dinas (No. 5) are about 1,100 feet thick, and rest on beds of purple and bluish purple slate, No. 4, about 400 feet in thickness, which undulate across the country with a western outcrop, and occupy a space from a quarter to three-eighths of a mile in width. They have been quarried for slate, and

* At the south-west corner of the sheet in the valley of Llyn Cwellyn.

it is in the equivalents of these beds that the principal works have been opened north of Llyn Peris, and in the Penrhyn slate quarries. In descending order they are succeeded by about 200 feet of grits, No. 3, similar to those of Dinas and Llyn Peris. They commence by the lake at a small promontory, and stretch for nearly 2 miles to the south-west, where they either die away or are lost in the glacial drift. From beneath them about 140 feet of slate crops out, No. 2, of a deep purple colour, pitching to the south-east at an average angle of 26°. In this division the principal slate quarries lie on the south-west side of the lake, although it is not more than half the thickness of the slaty strata that lie above the last-mentioned grits. Owing to the lowness of the ground, which is somewhat unfavourable for getting easily rid of rubbish, and also to the quality of the slate, due in part to numerous joints which cut up the body of the rock into fragments, these quarries have never been so successfully worked as those on the opposite side of the lakes, even although the cleavage is sufficiently close and fine, and either vertical or dipping at angles approaching 90° to the north-west.

Underneath the beds last described there lies a mass of conglomerate and grit, No. 1, already alluded to (p. 140), the absolute thickness of which varies, owing to its irregular passage into the porphyry that forms its western boundary.

By the lake near the Glyn slate quarries the base of the conglomerate is highly felspathic and sometimes crystalline, enclosing pebbles of felspathic trap, quartz-porphyry, quartz, quartz rock, purple and black slate, and red and green jasper. The whole mass is altered, the alteration increasing as it approaches the undoubted porphyry, and it is easy to note, first, the disappearance of the granular structure in the conglomeratic or sandy matrix, and its gradual assumption of a porphyritic character with small crystals of felspar embedded, while the enclosed pebbles still retain their distinctive forms; and again, approaching the recognized porphyry, the hard outlines of the pebbles in the conglomerate gradually melt away till they become indistinguishable in the general fusion of the rock: and the view, that the porphyry is not an intrusive mass in the ordinary sense—breaking through and tilting the strata—is aided by the fact that it is impossible to define any line of demarcation between conglomerate and porphyry, for, among other reasons, though the strata as a whole undulate to the south-east at low angles on the south bank of Llyn Padarn, yet the last dip is *towards* the porphyry, evidently without a fault. The alkali in the felspathic pebbles and in grains in the sandy matrix, would aid in this alteration. There is nothing in the appearance of the porphyry contrary to this idea, for its general character is that of a rock with an amorphous grey felspathic base (like that of the altered rocks adjoining), containing small scattered crystals of quartz, which are often somewhat *granular*, sometimes hexagonal, and sometimes they seem to be four-sided prisms, as if pseudomorphous. Like the altered strata it also contains small distinct crystals of glassy felspar. On the whole the rock tends to confirm the impression made on me by the rocks of Moel-gronw on the opposite side of the lake, that the porphyry itself may be nothing else than Cambrian rocks that have undergone the extreme of alteration (fig. 51, p. 141).

From Llyn Padarn the conglomerate* stretches to the south-west

* Opposite the letters "lyn" in Map 78 S.

ıting the purple slate and porphyry. It crosses the valley yn Cwellyn in a narrow strip, about half a mile below 's Garmon, and on the broken ground on the south-west f this valley the same general phenomena of alteration occur ıre so well seen on the banks of Llyn Padarn. Further the conglomerate forms the highest points of Moel-y-Tryfan Iynydd-y-Cilgwyn (75° N.W.), where it is partly metamor-d into a sort of talcose schist and conglomerate. Beyond t has been either completely obliterated, or curving round east near the crest of the hill is cut off by a fault that s the superincumbent purple slate directly against the yry.

will be gathered from part of the foregoing remarks that the grits of Llyn Peris and Dinas die off to the south-west at 's Garmon, the middle grits at Ceunant on the moor, and wer conglomerates disappear at Mynydd-y-Cilgwyn, but the slates that are interstratified with these follow an un-n course to the neighbourhood of the turnpike road near lyfni. South-west of Bettws Garmon they rise directly from the Lingula beds. By the lower lake of Nant-y-llef they rgely and successfully quarried close to the quartz por-which rises on the west of the lowest quarry like a wall in direct juxta-position with slate. The unpor-zed condition of the slate where it touches the porphyry, ıer with the marked occurrence of slickensides there, seem licate a fault. South of Llanllyfni the strike of Cambrian changes to east and west, and the purple slate does not south or south-west of Mynydd Llanllyfni and Ty Coch, Clynnog-fawr on the coast. The drift-covered district r south is composed of black and ferruginous Silurian shales and grey sandstones. The point furthest south purple slate has been observed is at Llwyd Coed, about e south of Llanllyfni, and to the west of the last named the ground is so obscure that the reason of the dis-rance of the slate in that direction is unknown. The fault d to above, which throws the slate against the porphyry, bably continued along the boundary of the trap as far as lyfni, and west of that village perhaps throw the slates down t the low Cambrian grits and conglomerates that form the rn boundary of the porphyry, from the mouth of the Pass of eris to Llanllyfni.

boundaries above described are, however, by no means te, for, being on both sides much obscured by drift, they are ıces mere approximations, and the absolute continuity of the yry itself is deduced from imperfect but probably safe data. though the underlying rock be unseen, the shape of the d aids the experienced eye, and the drift itself often lends of the nature of the rock immediately beneath, from which terial is frequently largely derived. A debris of large angular ents also often tells of the close neighbourhood of the parent and altered rocks lying in the assumed line of the margin of

the porphyry also assist. Further, wherever the drift has been removed in the area mapped as porphyry there it has been found. Some of these places may be named for the use of those who care about details.

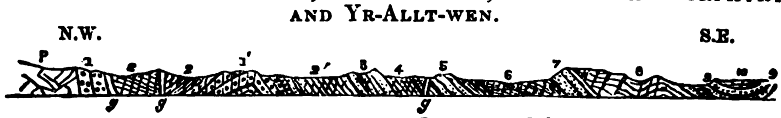
On the rail at Afon-Llyfni,* and from thence to Mynydd-y-Cilgwyn, the slopes are rough and rocky, and the quartz porphyry is everywhere visible. Next it is seen in the brook at Melin Forgan, and at Ty-newydd, Moel, Caerwen, and several places on the river Gorfai, after which, except at one place on its western edge, north-east of the Caernarvon and Beddgelert road, it is entirely obscured by drift, till it again stands boldly out on the rocky ground that overlooks Llyn Padarn and the river Rothell. On the opposite side of the lake it forms the crags of Clegir and Moel-gronw, and traces of the same kind of rock occur as far north as Craig-y-Nyth, beyond which to St. Ann's chapel, a broad level tract of country is entirely obscured by turbary and deep glacial drift, largely charged with miscellaneous boulders derived from the neighbouring mountains. In the year 1850, however, a shaft was sunk by Colonel Pennant between St. Ann's chapel and the Penrhyn slate quarries, and there the porphyry was found, at a point where it might be expected if it were continuous so far north-west, for there seems no good reason, except the covering of drift, why it should suddenly disappear on the hills above Llyn Padarn. That it does not cross the river Ogwen is certain, but it is probably close beneath the thick beds of slate that immediately underlie the uppermost Cambrian grits in the anticlinal curve between Bethesda and the bridge.

Such is the general relation of the porphyry to the stratified Cambrian rocks, and I shall now proceed with a more minute description of the latter on the north side of the lakes of Llanberis.

On the north side of Llyn Padarn there are certain bands of grit, shown in the following diagram, some of which do not appear on the south.

Fig. 52.

SECTION BY THE RAILWAY, LLYN PADARN, BETWEEN THE PORPHYRY AND YR-ALLT-WEN.



P. Porphyry. *g.* Greenstone dykes.
1 to 10. Cambrian conglomerates, grits, and slates.

P represents the porphyry, which bears the same relation to the neighbouring conglomerate that it does on the opposite side of the lake, and the phenomena are so instructive that I give a second description, even though almost the same in both places. The blueish grey felspathic base of the porphyry encloses small hexagonal and four-sided crystals of felspar. Grains or

* Map 75 N.W.

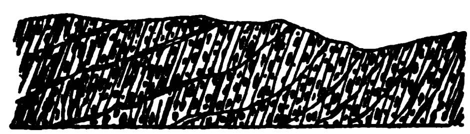
rather imperfect crystals of very clear quartz are also dispersed in the base, the result apparently of attempts at crystallization, or possibly in some cases relics of a rock of which the porphyry is the thoroughly altered representative. As on the opposite shore, there is a gradual passage from porphyry to the conglomerate and grit No. 1. The latter, near its margin, has often a grey felspathic base similar to that of the adjoining porphyry. Felspar crystals and granular or more perfect quartz crystals also occur in it, decreasing in quantity with increased distance from the porphyry and diminished alteration of the rock.

A little farther from the porphyry, the base includes traces of quartzose and felspathic pebbles, the indistinct outlines of which are seemingly due to the partial fusion of their edges into the once-melted enveloping matrix. Further off, the pebbles become more distinct, the granular quartz crystals still continuing, and by degrees the whole rock passes into a comparatively unaltered conglomerate. No. 2 is purple slate lying in a trough, and the grits and conglomerates 1′ that rise from beneath are identical with those of No. 1, but, though so near, yet thicker; thus affording additional evidence that on the west side of the synclinal bend a part of these beds has been melted and used in the formation of the porphyry. The rocks marked 1′ are also altered, even though, at the surface, 600 or 700 feet distant from the porphyry; still further evincing, in my opinion, not the mere intrusion of an igneous mass below for the special alteration of this conglomerate, but rather, that here, the rocks on this horizon, before the conclusion of the Lower Silurian period, were partly melted and partly altered deep beneath the surface, and thus it happens that, exposed by denudation, melted and altered rocks alike rise and fall with the anticlinal and synclinal curves that affect the rocks of the country; the porphyry itself having nothing to do with the production of these disturbances.

Part of the conglomerate 1′ (fig. 52) consists of slaty pebbles in a slaty matrix, the whole being affected by slaty cleavage, remarkable on account of the pebbles being elongated in the direction of the cleavage lines, and obliquely to the planes of

Fig. 53.

PEBBLES ELONGATED IN THE LINES OF CLEAVAGE.



bedding, in accordance with which under ordinary circumstances the flat sides of the pebbles would naturally lie; this arrangement being due to intense pressure, which, in all cases of slaty cleavage, caused the particles composing the rock to arrange themselves approximately at right angles to the direction of the force. In

this case, these effects are *visible*, the pebbles having been lengthened and flattened by the same pressure.*

The higher part of 1′ consists of green and purple grits underlying green and purple banded slates 2′ (=2) overlaid by a thick hard grit marked 3, which thins rapidly out on the slopes above or else passes into slate by change of material. By the lake it is overlaid by other bands of green and purple banded slate, alternating with grits, marked 4 and 5. Resting on these are purple slates, 6, underlying a band of thick-bedded grit, No. 7, which crops out on the woody crags at the western end of Yr-Allt-wen.

By reference to the 1-inch map† it will be seen that the Cambrian beds above described first strike northerly, and then curving east and south-east, abut on a fault that runs north from Llyn Padarn. The uppermost grit, No. 7 of the diagram, is overlaid by a great mass of purplish blue slate, No. 8, which, highly contorted and intersected by three principal north and south faults, forms nearly the whole of Yr-Allt-wen, extending east as far as a marked band of grit that strikes northward from Llyn-Peris a little east of Pont-y-Bala. This band at Llyn Peris dips west beneath the "blue slate" which is thus, but for small interruptions caused by faults, entirely underlaid and enclosed at the surface by the grit on the east, north, and west. Above the "blue slate" there is by Llyn Padarn a thin band of grit, No. 9 of the diagram. It curves contortedly up the south slope of Yr-Allt-wen, and resting on it are purple slates No. 10.

The last and uppermost three divisions, all along the shore of Llyn Padarn, are mere denuded repetitions of beds further east; for the "blue slate" of Yr-Allt-wen is the equivalent of that of the great Dinorwic quarries, on the steep slopes above Llyn Peris, and the overlying band of contorted grit by Llyn Padarn represents the thin band that at Llyn Peris lies close above the blue slate. Further the uppermost purple slate 10 on the shore of Llyn Padarn is the precise equivalent of the highest Cambrian purple slate of the district, viz., those that lie between the thin grit band on the map, and the green slate that immediately underlies the 1,300 feet of grit that forms the ridge of Elidyr-fach. Such is the section along the north shore of Llyn Padarn, an analysis of which unexpectedly shows that all the Cambrian beds of the Llanberis district are present at Llyn Padarn, with the exception of the uppermost green slate and the Cambrian grits of Elidyr-fach that immediately underlie the Lingula beds.

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* I first observed this fact in 1848, and in 1849 pointed it out to Sir Henry De la Beche and the late Professor E. Forbes, but for a time they would not admit what seemed to them so novel an idea. It was with much satisfaction that I afterwards saw a similar case described by Mr. Daniel Sharp, in his memoir "On Slaty Cleavage," published in 1848. I did not, however, till the publication of Mr. Sorby's mmeoirs, understand the cause of this phenomenon, now so well established by his writings and those of Dr. Tyndall.

† 78 S.E.

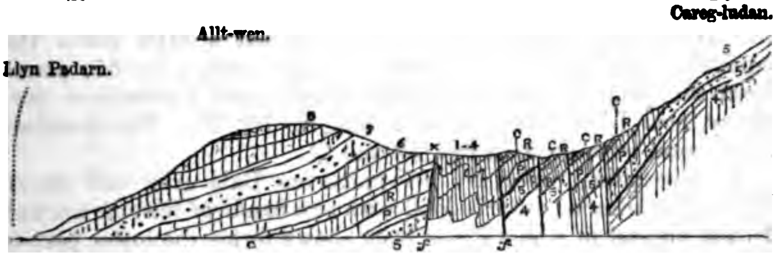
I shall now explain the structure of the country a little further north.

Above the old tramway, half a mile west of Elidyr-fach, there is a triangular tract of grit (No. 5, fig. 54).* An old road, long since closed, runs through it, and nearly in the midst stands the cottage of Careg-ludan. At one of its southern angles it is faulted against the grit No. 7, that lies beneath the "blue slate" of Yr-Allt-wen. Partly obscured by drift this mass of grit cases the south side of the hill in the manner shown in fig. 54, and where unfaulted it dips on the south *beneath* the purple slates that in a crescent form lie immediately north of Yr-Allt-wen, and end in the middle of the little bay about the middle of Llyn Padarn. The purple slates immediately south-east of the Careg-ludan grit are the same. They occupy a triangular piece of ground about a mile long and half a mile wide, that lies between the grits and two faults that strike from Llyn Peris towards Marchlyn-bach, and where unfaulted, resting on the Careg-ludan grit, they underlie the narrow strip that runs along the eastern limb of the letter N. on the map. A south-west section from Careg-ludan to Llyn Padarn gives the following general arrangement of the strata. The numbers correspond to those in diagram No. 51.†

Fig. 54.

SECTION FROM CAREG-LUDAN TO LLYN PADARN.

S. N. Careg-ludan.



1. Grits. 2. Slates.

No. 5 represents the grit of Careg-ludan, and 6 the purple slaty series below the grit 7, which grit underlies the "blue slate," No. 8, of Yr-Allt-wen. The fine dark purple slate quarries of Allt-ddu lie in the hollow near the outcrop of No. 5.‡ The faults marked *f* in the diagram are indicated on the map, but the others nearer Careg-ludan are too small and close to be noticed on the 1-inch scale. They are all easterly downthrows, and in the hollow repeat the lower part of the strata No. 6 three times. These rocks contain certain bands by means of which the faults were detected by Mr. Griffith Ellis in ground otherwise very obscure. The highest beds, immediately below grit 7, are of purple slate, beneath which is a thin band of calcareous

* The equivalent of No. 5 in Fig. 52. *See also* 1-inch Map, 78 S.E.

† The horizontal scale is 4 inches to a mile, the vertical merely sketched.

‡ Two quarries were worked in equivalent beds between grits 5 and 7 west of Allt-wen.

sandstone marked C, overlying a red slate marked R, which rests on a purplish blue slate P, lying on grit No. 5. West of the ground affected by the minor faults there are two large parallel faults marked *f*, running north from Llyn Padarn, and crushed between them lies a narrow strip of purple and green slaty rocks running right across Yr-Allt-wen in an unexpected position, for these slates are the equivalents of the beds that immediately rest on the altered conglomerate that adjoins the porphyry (1 to 4, fig. 52). The purple slates (6) abut on the most westerly of these faults, as shown in fig. 54 at ×.

North of Careg-ludan, on the moor (Waun-gynfil) the rocks are almost entirely obscured by drift, but several indications show it to be probable that the grits strike across the moor in narrow bands to the Penrhyn slate quarries, where, on the west side of the quarry, they appear in order similar to that above the lakes, but less disturbed.

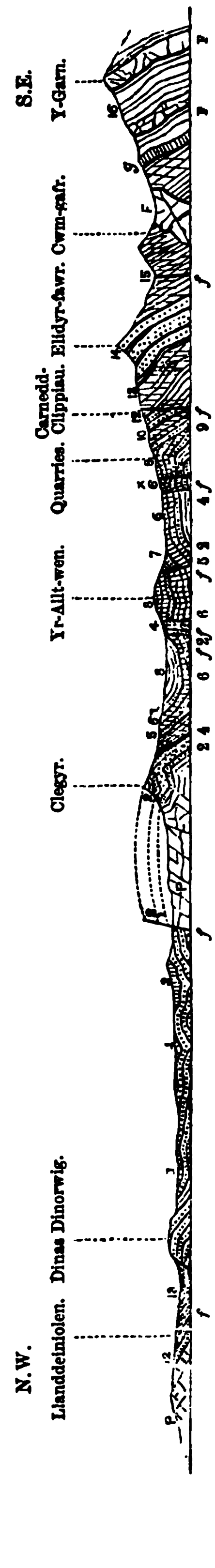
I have thus far explained the Cambrian section in ascending order, because the superposition of all the lower strata near the porphyry is easily seen by help of the railway cutting. The middle ground is difficult, but clear when attentively studied; and the order of the upper beds, close by the thick grits of Elidyr-fach, again becomes plain when carefully unravelled. That the mutual relations of the whole of the rocks of the district between Llanberis and Nant Francon may be thoroughly understood, I shall now describe the beds in descending order, beginning with the overlying Silurian strata on an horizon a little below the equivalents of the Bala limestone. The section, fig. 55, passes from the peak of Y-Garn to the Bangor and Caernarvon porphyry, near Llanddeiniolen, in a line N. 15° W. The numbers correspond with those in figs. 52 and 54.

In descending order, No. 16 represents Bala grits and slates, highly fossiliferous, interbedded with two bands of felstone marked F, the highest of which it has been shown forms the lower part of the great mass of felspathic porphyry that forms the base of Snowdon (pl. 28, Nos. 2 and 3, and figs. 30, 31). *g* is a line of greenstone intruded between the lines of bedding, and to the west of the intrusive porphyry of Cwm-gafr (*F*) are beds of highly cleaved slate, No. 15, dark in colour, especially towards the base. No fossils have been found in them, but it is probable that the lower part, which rests on the Lingula grits (14) of Elidyr-fawr may represent a low part of the Llandeilo flags. The ferruginous slaty beds of the Lingula flags (13) are here faulted against the Cambrian grits of Elidyr-fach (12), and immediately underneath these is a band about 20 or 30 feet thick of *green slate*, which in this area is very constant, being invariably found under these grits in all the Caernarvonshire sections. It is underlaid by the uppermost bands of purple slate, No. 10, and these are separated from the "*blue slate*" (8) (purplish blue) by a band of grit from 4 to 6 feet thick, No. 9, which is found precisely in the same position on the eastern side of the Penrhyn slate quarries in Nant Francon.

The principal quarries at Llanberis are in the "blue slate" on

Fig. 55.

SECTION FROM Y-GARN BETWEEN LLANBERIS AND NANT FRANCON TO LLANDDEINIOLEN.



Cambrian grits, conglomerate, and slates. — 1 P Porphyry. — Cambrian slates and grits. — Lingula beds. — Llandeilo and Bala beds.

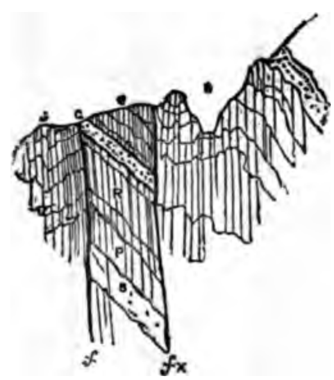
1, 5, 7, 9, 12. Grits. } Cambrian.
2, 4, 6, 8, 10, 11. Slates. } Cambrian.
13. Lingula flags. } Silurian.
14. Lingula grits. } Silurian.
15, 16. Caradoc or Bala beds } Silurian.

F. Felspathic lava beds.
G. Greenstones, intrusive.
P. Porphyries, intrusive.
f. Faults.

the side of the hill north of Llyn Peris, and these beds are the precise equivalents of the "blue slate" of Yr-Allt-wen, above Llyn Padarn, fig. 54. Its absolute thickness at the quarries in question is not very great, but the same beds (No. 8) being repeated by contortion, and the cleavage cutting through the whole nearly vertically, the body of slate appears to be much larger than it really is to those who are unable to detect faint signs of bedding unobliterated by cleavage. An enlargement of part of fig. 55 below × gives the following details:—

West of the "blue slate" (8), between two faults close together marked *f*, *f*×, is a long narrow strip of rocks which belong to the series marked No. 6, and are the equivalents of part of the rocks indicated in the detailed section No. 53.

Fig. 56.



8. "Blue slate."
f, *f*×. Faults.
6. Purple slate at the top.
C. A band of calcareous grit.
R. Red slate.
P. Purple slate.
5. Grit, which is the equivalent of those marked 5 in diagrams Nos. 52 and 54.*

Westward of these faults, as shown in fig. 54, the strata marked 6 are repeated. In these beds the Allt-ddu quarries are situated, which, as already stated, are the true equivalents of the abandoned quarries above the north shore of Llyn Padarn half way down the lake, and also of the Glyn quarries on the opposite shore. With sundry contortions they dip westward, on the north shore of the lake, and on them rests the band of grit (7) that runs from the western part of Llyn Peris to the north. It is thrown down by a small fault to the east, and, as shown in the section, the same grit must run through the middle of Yr-Allt-wen overlaid by the "blue slate" (8) on the top of the hill. West of this, between two faults that cross the hill from north to south, are purple and

* It is the prolongation of these faults on the opposite side of the lake that throws in the strip of Lingula beds between the broken masses of Cambrian grit on Pen-Careg-Fran.

banded green slates, marked 2 and 4, equivalent to those that rest on the conglomerates of Clegyr. (*See also* fig. 52.) Between the faults and Clegyr the "blue slate" (8) and the underlying grit (7) are again rolled in on the surface in a synclinal bend, and westward of these the lower grits, conglomerates, and banded slates, Nos. 1 to 6, crop to the surface in succession. The top of Clegyr consists of slate lying in a trough of highly altered conglomerate, No. 1. The above analysis shows that, as a whole, between the west side of Carnedd-Clippiau and Clegyr the country as it now stands lies in the form of faulted anticlinal and synclinal axes. The "blue slate" (No. 8) which crops to the surface from beneath the great mass of the Cambrian grits of Elidyr-fach, rolls over to the westward, and partly undenuded, is caught on the top of Yr-Allt-wen, and rises on the western slope of that hill facing Clegyr.

On the north-west side of the porphyry (P) the conglomerate and grit (1) and the lowest slates (2) are again thrown in on this line of section by a fault, small at this end, but gradually increasing on the north-east towards St. Ann's chapel. The conglomerate is well shown at Llys Dinorwig and on the hill of Dinas Mawr above the railway, and banded coarse slaty beds (2) resting on them may be seen much contorted in the neighbouring railway cutting. They apparently lie in a trough, which widens on the north in the manner shown in the 1-inch map, and they are the equivalents of the lowest slaty beds that encircle the base of Moel-y-ci, three miles to the N.E. The eastern boundary of the trough is certain, but that on the west is much obscured by drift. Beyond it to Dinas Dinorwig* there are thick beds of hard grit and conglomerate (1), much concealed, but the general nature of which is shown on the banks of the river Rothell and on the Seiont. South-west of the river the country is equally covered, but wherever rocks in place rise through the drift they are grits and conglomerates.

Between Dinas Dinorwig and Llanddeiniolen is the Aber and Dinlle fault already alluded to (p. 140). It will be more fully described further on (p. 162), but in the meanwhile it may be stated that being a very large downthrow on the north-west, its effect here is to throw in the black slates (13) against the lowest Cambrian grit of the district, which in fig. 55 is marked rising in the hill crowned by the old camp of Dinas Dinorwig. It is, however, likely that these black slates may be Llandeilo beds, which overlapped the Lingula beds before denudation, and here lie directly on Cambrian grit. From beneath these Silurian slates the uppermost Cambrian grit (12) rises at Llanddeiniolen. This grit is very much altered, and adjoins the granitic rock (P) that runs from Bangor to Caernarvon.

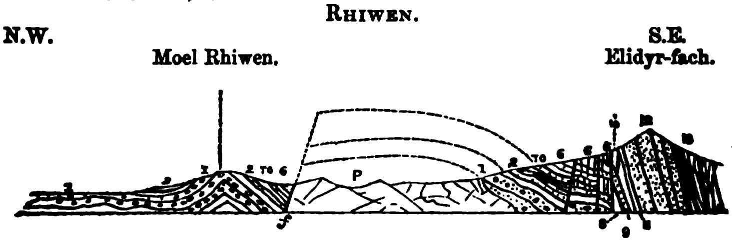
The foregoing description applies to the rocks at Llanberis north of the lakes, and as the "blue slate" (8) is there most valu-

* Slaty beds appear below the south-east side of Dinas Dinorwig, but they are so poorly shown and so quickly lost under drift that it was impossible to trace them on the map.

able, it will some day be of importance to know if it is continuous beyond the present Dinorwic quarries towards Marchlyn-bach, on the moor further north. In these quarries, as shown in fig. 56, the lower part of the "blue slate" is not reached, being cut out by the fault *f* x, against which it is thrown; and if that fault be followed in its probable northward continuation, it appears likely that for at least a quarter of a mile the "blue slate" is entirely cut out on the slope of the hill, there being no space for it between the fault and the uppermost purple and green slates that immediately underlie the grit beds of Elidyr-fach. If this be correct, it seems unlikely that the "blue slate" (8) again rises to the surface till we approach Marchlyn-bach, and the following section, drawn north-west from Elidyr-fach, gives the probable arrangement of the strata in descending order, at a point where the "blue slate" is cut out at the surface by a fault.

Fig. 57.

SECTION ACROSS THE CAMBRIAN ROCKS FROM ELIDYR-FACH TO MOEL RHIWEN.



P. Porphyry.
1. Conglomerate.
2. Purple slate.
3. Grit.
4. Purple and green banded slate.
5. Grit.
6. Purple slate.
8. "Blue slate" (blueish purple).
9. Grit.
10. Purple slate.
11. Green slate.
12. Thick grits (1,000 feet).
13. Lingula flags.

Cambrian. Faults.

On the south-east we have first, the base of the Lingula slates, No. 13, overlying the uppermost Cambrian grits (12), which rest on light green slate (11), below which is a purple slate (10) followed by the thin grit band (9), which in the quarries divides the upper purple and "blue slate" (8). Here the "blue slate" is entirely cut out at the surface by the most easterly of three faults, while its probable position underground is represented. Between the faults the lower purple slate (6) forms the surface, and further west the succession of slates, grits, and conglomerates is continued down to the porphyry marked P. Beyond the porphyry the same slates and grits are repeated on Moel Rhiwen by a fault. They dip easterly, are not specially altered, and abut on the porphyry by the increase in this direction of the same fault that in fig. 55 merely throws against it the conglomerate No. 1.*

* The reasons for considering this boundary line to be a fault are explained, p. 153.

It is at present impossible, without special excavations, to say at what point further north the "blue slate" may again crop out to the surface on its passage to the Penrhyn quarries in Nant Francon, but with the imperfect knowledge that may be gleaned, it seems probable that clear of the faults it may rise to the surface from an eighth to a quarter of a mile S.S.W. of the outlet of Marchlyn-bach, from whence, unless again cut out by drift-concealed faults, it may continue unbroken to the Penrhyn slate quarries.

If this inference be correct, then about a quarter of a mile N.N.E. of the efflux of Marchlyn-bach, the arrangement of the rocks generally, and the position of the upper slates in particular, would be nearly as represented in the section that runs from Y-Glyder-fawr over Moel-y-Ci to the Menai bridge.* It must, however, be recollected that where that section crosses the moor of Waun-gynfil between Marchllyn-mawr and Moel-y-Ci the boulder-drift is so deep that for more than 2 miles the position of the porphyry, slates, and lower grits, as laid down, was inferred from evidence obtained further to the north and south. Between the Lingula grits at Marchlyn-mawr and the base of the Cambrian grits (near Marchlyn-bach) there can be no hesitation in drawing the rocks as they are shown in the section, but west of that the conglomerate (No. 1 of fig. 57) is supposed to be obliterated by excessive alteration. The evidence of this is certainly imperfect, but from symptoms discovered between the Penrhyn slate quarries and St. Ann's chapel, it seems to point in that direction.†

In the midst of the turbary, on the north-west side of the porphyry, a boundary line is drawn, already alluded to as a fault. It runs from Bryn Efail opposite Cwm-y-glo‡ to St. Ann's chapel,§ and the cross roads near Tan-y-Graig,‖ from whence it passes northward on the east of Gyrn to the higher part of Afon-y-garn and into the Aber river, where it probably ends against a north-west fault near Aber. The reasons for considering that the north-west boundary of the Llyn Padarn porphyry is a fault are as follows:—

On the north-west side of the quartz porphyry, near the village of Llanbabo, there are marked on the map four sets of beds of conglomerate and grit, which I have stated are the general equivalents of the four conglomerates and grits that lie on the north shore of Llyn Padarn, between Clegyr and Yr-Allt-wen (fig. 52). Though all dipping easterly, and on opposite sides of the porphyry, the succession of strata near Clegyr and on Moel Rhiwen and Drysgol-fawr is the same. East of the porphyry, on Clegyr, there is a coarse conglomerate at the base, overlaid by purple and green streaked slates interstratified with three bands of grit. West of the porphyry, on

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* Six-inch Sheets No. 31, line 2, and No. 8, fig. 2. Pl. 28.

† *Field geologists* will readily understand how the mind often arrives at probable conclusions, difficult or impossible of absolute proof, from a kind of evidence only appreciable by those who have studied and worked out a country foot by foot.

‡ Half a mile north-west of the efflux of Llyn Padarn.

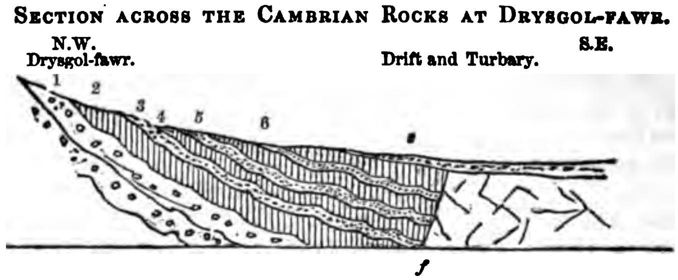
§ At the entrance to Nant Francon.

‖ East of Bethesda.

Moel Rhiwen and Drysgol-fawr, there is precisely the same arrangement of strata, and the beds striking south-west and south, with an easterly dip, must abut on the porphyry towards Llanbabo. But it may be said, why introduce a hypothetical fault, when the porphyry being intrusive may anywhere cut off part of the invaded strata, more especially since, on the opposite side of the lake, porphyry and conglomerate pass into each other insensibly? The reply is, that on the south-east side of the porphyry the grits and slates, No. 1 to 8, dip easterly in such a way that if prolonged (in spite of such minor undulations as that of Clegyr) they would still rise somewhat above the present surface of the trap in the manner indicated by the dotted lines in figs. 55 and 57, and the fact that a set of beds appear dipping *easterly* on the west of the porphyry, the same in number, arrangement, and lithological character as those on the east, affords sufficient evidence that the Rhiwen strata, from 1 to 6 (fig. 57), are the same beds repeated by a fault, which by the side of the river opposite Cwm-y-glo throws the lowest conglomerate at the surface against the porphyry; and this fault increasing to the north-east, the purple and green slates, No. 6, and perhaps part of the "blue slate" below *s*, well up in the series, strike directly against it in the manner shown in the following diagram, at the fault marked *f*.

Fig. 58.

SECTION ACROSS THE CAMBRIAN ROCKS AT DRYSGOL-FAWR.



West of the porphyry, the same strata strike towards St. Ann's chapel in Nant Francon, and as they appear to dip south-east, and as their precise equivalents in the Penrhyn slate quarries (the porphyry being concealed by drift) also dip in the same direction (fig. 60), the fault may be considered certain. Across the river Ogwen, in the same north-east line, the uppermost Cambrian grits (No. 12 of the diagrams) and the Lingula flags are found to be thrown down to the west by a fault of about 2,000 feet, and this concludes the evidence.

Valuable slate beds may perhaps lie under the drift and turbary of the high plateau between Llyn Padarn and Bethesda, but, without sinking, there is no means of determining the precise nature of the beds marked *s* (fig. 58). Probably they are little more than 100 feet thick. Their position proves that the lower beds belong to a high part of the purple strata that underlie the "blue slate," and it seems not unlikely that some of the latter [redacted]

occur there or not, the drift is so deep, and the shape of the ground is generally so unfavourable for quarrying, that, at present, it seems unlikely it will be turned to use.

The Drysgol-fawr strata (Nos. 2 to 5) are repeated on Moel-y-Ci, rolling over in a gentle anticlinal, and rising in a synclinal axis on the north-west side of the hill. At its base the lower conglomerates (No. 1) rise to the surface, and continue as far as the Aber and Dinlle fault, along which Lower Silurian strata are thrown down on the north-west against the lowest member of the Cambrian strata in Caernarvonshire, in the manner shown in fig. 55.*

CHAPTER XXI.

CAMBRIAN ROCKS—*continued.* NANT FRANCON; THE VALLEY OF THE OGWEN.

The Cambrian section on the Ogwen between Nant Francon and Bangor is essentially the same as that in the Pass of Llanberis, but simpler, for the strata are less faulted and contorted. The rocks which by the lakes of Llanberis occupy a breadth of 2½ miles, here, close to the Penrhyn quarries, lie in a breadth of little more than half a mile between Bronllwyd and St. Ann's chapel (figs. 59 and 60). North of the Ogwen, near Llanllechid, the structure of the country is even less complicated, for many of the faults that break the strata further south cease at the river, and, the porphyry also being absent, there is an unbroken ascending section from the lower Cambrian conglomerate to the Lingula beds near Bethesda, east and south of Llanllechid (fig. 61, p. 158)

Penrhyn Quarries and the Valley of the Ogwen.

The details of the structure of the country are as follows:—

Between Heaterstone† and the Penrhyn quarries deep boulder-drift continues to hide the rocks. The general position of the slate is, however, unmistakeably indicated by the unbroken strike of the grits of Bronllwyd. Looking to the S.W. up the Penrhyn slate quarries, the strata lie generally as they are drawn in the diagram on the next page.‡

The numbers of the beds correspond with those of the Llanberis quarries The grits of Bronllwyd (No. 12) dip nearly east at an angle of about 60°. The usual green slates (No. 11) crop from underneath. These are succeeded by the upper purple slate (No. 10) separated by the thin bed of grit (9) from

* Also 6-inch sections, sheet 31, line 1, and 1-inch map.

† Half way between the Llanberis and Penrhyn quarries.

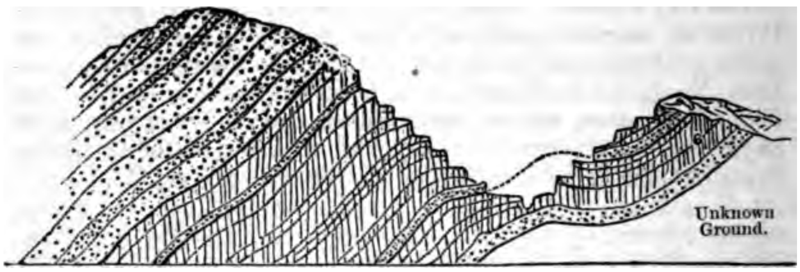
‡ The scale not being measured, it must be looked on as a sketch, and not as a true section. It is horizontally about 5 inches to a mile.

Fig. 59.

SECTION OF THE PENRHYN SLATE QUARRIES.

S.E. N.

Bronllwyd.



5, 7, 9, 12, Grits } Cambrian.
6, 8, 10, 11, Slates }

the "blue slate" (8), the colour of which becomes more purple towards the beds near the bottom of the quarry. Under this is the grit (7) equivalent to the grit that underlies Yr-Allt-wen at Llyn Padarn. Beneath it, in the very bottom of the quarry, is the purple slate (6). Part of these strata, including a portion of the "blue slate," curves over to the west in an anticlinal axis, and immediately rises in a minor synclinal curve, so that besides forming the greater part of the quarry on the east, a part of the "blue slate" also occurs in the terraces on its western side. For a space the grit No. 7 is exposed in a curving line in the bottom of the quarry. Its outcrop and that of the lower slate (No. 6) are supposed to be hidden by the rubbish from the quarry, which, with the drift and alluvium in the valley, conceals the uprise of the quartz porphyry towards St. Ann's chapel. It is probable that the lowest green and banded purple slates and conglomerate of the Llanberis section are here cut out by the occurrence of the porphyry higher in the Cambrian series than the beds which pass into it on the shores of Llyn Padarn. West of the porphyry on the moor the order of the rocks has already been explained (p. 154).

A general section drawn from Cwm-graianog across the slate quarries to the neighbourhood of Llyn Cororion * gives the following arrangement of the strata on the left bank of the river Ogwen, from the Lingula flag downward.† (Fig. 60.)

No. 15 represents the base of the Bala beds, and perhaps the black slates of the Llandeilo flags; Nos. 14 and 13 the Lingula grits and slates; 12 to 6 the strata just described in the Penrhyn quarries, below which is the quartz porphyry P. Between the faults *a* and *b* the usual succession of purple slate and grit occurs down to the conglomerate No. 1, which is probably not far beneath the surface at *b*. Between the faults *b* and *c* part of the same grits, and green and purple banded slates from 2 to 6, are repeated in an anticlinal curve, which widens on the south-west by Ffynnon-bach, as shown in the 1-inch map. Between the faults *c* and *d* the purple and banded slate No. 2 is again let in in an irregular space. The trigonometrical station above Pont-y-Coetmor stands on it. A narrow strip, about a mile in length, of the basement conglomerate (No. 1) is then let in between two faults, *d*, *e*, downthrows on the south-east and north-west. Pen-y-garth stands on it. The fault *e* again throws in the purple banded slate No. 2, from beneath which the conglomerates (No. 1) crop out in regular succession as far as the Aber and Dinlle fault *f*,

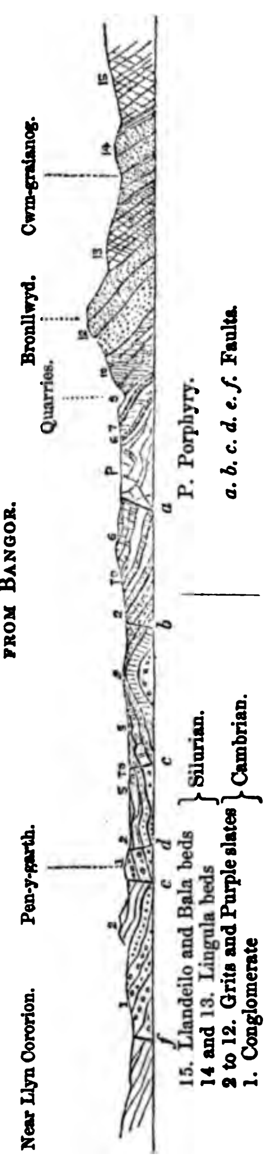
* 2½ miles S.S.E. from Bangor,

† It corresponds to the 6-inch sections, Nos. 28 and 31, and plate 28, fig. 3, from Snowdon to Dinas, across the Llanberis country, and to diagram No. 55, p. 149, on the N.E. side of the lakes, and at a glance brings the positions of the same beds before the eye in the nearly parallel valleys of the Ogwen and Llanberis.

where Lower Silurian beds are thrown in on the west near Llyn Cororion.

On Moel-y-Ci and in the neighbourhood of the valley of the Ogwen generally there is a considerable modification in the lithological character of the Cambrian rocks, compared with those of Llanberis. Some of the slates become much more sandy, and occasionally absolutely pass into grits, so that the section differs in the details of its lower members from the type section at Llyn Padarn. Thus on the top of Moel-y-Ci there is a bed of conglomerate and grit unknown on Drysgol-fawr, but an equivalent of which may perhaps be concealed dipping towards the porphyry beneath the turbary. In spite of local variations, however, a glance at the map, with the assistance of the preceding diagrams, will show that as far north as the Ogwen the detailed structure of the country may be dissected. Beyond the Ogwen, on the east, the more simple arrangement of the rocks resembles that south-west of Llyn Padarn, above the porphyry, and, though much obscured by drift, I believe I succeeded in accurately laying down the general distribution of the rocks round Llanllechid. As this is also a country that has been worked for slate, I shall devote a few paragraphs to the explanation of its structure.

Fig. 60. SECTION FROM CWM-GRAIANOG ACROSS THE PENRHYN SLATE QUARRIES TO LLYN CORORION, 2¼ MILES FROM BANGOR.



The uppermost Cambrian grits of Bronllwyd strike north across the Ogwen behind the hamlet of Tan-y-graig, dipping a little south of east at angles of about 60°. (*See* Map 78 S.E.) Being thrown down to the west by the Bryn Efail and Aber river fault, they spread westward to Bethesda (sometimes called Glan Ogwen), over a space more than half a mile in width, rising in an arch, the top of which being partly denuded a portion of the upper green and purple slates reach the surface in the form of half an oval, between the turnpike road and the north-west fault. (Fig. 61.) This fault passes down the course of the river from the bridge above Bethesda to Pont-y-Coetmor, and may be termed the Ogwen fault. Being a downthrow on the N.E., it throws the uppermost grit opposite Bryn-llys against the lower slaty series that lies beneath the turbary. A little beyond, on the right bank of the river towards Coetmor, the lower part of the lower grits associated with the lower purple slates follow a curved and faulted line, as shown on the map by Llanllechid, and abut on the Aber and Dinlle fault near the house called Tan-y-marian, about 2 miles S.E. of Bangor. The above description will be made plainer by reference to the following line of section drawn close on the right bank of the Ogwen from Felin Cochwillan* to Bwlch-hela,† in which the arrangement of the strata as follows (Fig. 61):—

From Bwlch-hela to Tan-y-graig the Lingula grits (14) and slates (13), and

* Opposite the 27th milestone on the Holyhead road, on the right bank of the Ogwen.

† A mile and a half south-east of Bethesda.

the Cambrian grits (12), and slates, probably as low as the "blue slate" (8), retain the same general position that they have at and above the Penrhyn quarries. The ground by Tan-y-graig is partly obscured by drift, but I have no doubt of the existence of true Cambrian slates in a narrow space about a fifth of a mile in width between Ogwen bank and the country a quarter of a mile N.N.E. of Ciltreflys, where it is cut off by the Bryn Efail and Aber river fault, which here throws the black Lingula slates against it on the east bank of Afon-Fridd-lâs, a little above the Penacneddr road. The rocks are thus partly repeated, and in the line of section the grits (No. 12) roll over in an arch in the centre, again bringing the upper purple slates to the surface at ×. The 30th milestone must be about the middle of the curve. Cropping again to the west in the town of Bethesda, the whole of the rocks, including the green, upper purple, "blue," and part of the lower purple slates rise between the town and the boss of grit No. 3, on which stands the ruined mansion of Coetmor. Certain of the intermediate grits below the "blue slate" seem here to be entirely concealed by drift, or else (more probably) they have thinned away, or their equivalents have become slaty in texture, so that the grit on which Coetmor stands is in the midst of the lower purple slates, and probably represents the grit marked No. 3 on the shores of Llyn Padarn and on Drysgolfawr. (Figs. 52 and 58.)

Coetmor stands on the centre of an arch of grit, dipping east, north, and north-west, and the lower part of the slaty beds that rest on its eastern dip curve round a little north of Coetmor (*see* 1-inch map), and lie in a synclinal trough nearly a third of a mile in width between the grit on which the mansion stands and the road leading down to the bridge across the Ogwen called Pont-y-Coetmor. Here the same grit rises with a south-eastern dip, striking by Coed-isaf to Llanllechid, and from thence by Rhiw-goch to the Aber and Dinlle fault *f**, on the west of which Lower Silurian rocks (15) are thrown in. Underneath it the lower part of the purple slates (2) crop out. They rest on the basement conglomerate (1), and are generally very sandy, and sometimes almost gritty in quality, representing in part some of the lowest

* Three miles E.S.E. of Bangor.

Fig. 61.

SECTION ON THE RIGHT BANK OF THE OGWEN FROM FELIN COCHWILLAN (2 MILES S.S.E. FROM BANGOR) TO BWLCH-HELA ABOVE NANT FRANCON.

N.W. S.E.

Felin-cochwillan. Cochwillan. Near Pont-y-Coetmor. Coetmor. Bethesda. Tan-y-graig. Bwlch-hela.

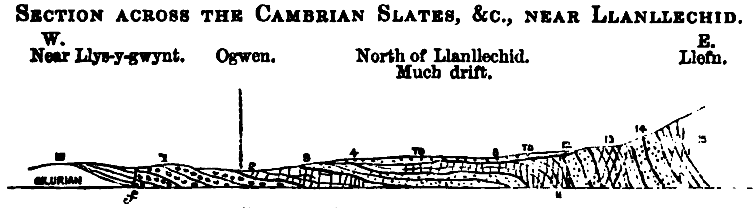
1. Conglomerate
2 to 12. Slates and Grits } Cambrian.
13. Lingula Slates
14. " Grits } Silurian.
15. Llandeilo and Bala beds, Silurian.
f. Faults.

beds of grit that lie north-east of Moel-y-Ci. To explain the nature of these local variations, I may recall the fact that, whereas both the middle and upper grits and conglomerates thin out and disappear on the south between Llanberis and Bettws Garmon, the opposite result takes place in the extension of these strata from Llanberis northward, several new beds of grit appearing between the lakes of Llanberis and the Ogwen. Again, that certain grits that are separate on the west seem to coalesce on the east side of the river, either by a thinning of the intermediate slate or by its assuming a more sandy texture. This is especially characteristic of the rocks east and north of Moel-y-Ci, as for instance near Waun-hir, where sandy slates become rapidly mingled with thin bands of conglomerate, which as rapidly disappear, probably evincing the shallowness of the water in which the original sediments accumulated.

The country for some miles north and north-west of Bethesda is generally so deeply covered by drift and boulders that it is impossible to unravel its details with the same accuracy as in the section last described. Possibly certain beds of grit occur between the purple and blue slate quarries north or north-east of the Holyhead road, and these grits may crop up to the drift in the great triangular space coloured as slate on which Llanllechid stands. However this may be, the following diagrams will explain all the larger relations of these rocks north of Bethesda.

Fig. 62.

SECTION ACROSS THE CAMBRIAN SLATES, &c., NEAR LLANLLECHID.



15. Llandeilo and Bala beds }
14. Lingula Grits } Silurian.
13. „ Slates }
12. Grit }
4 to 12. Purple and "blue" Slates, &c. }
3. Grit } Cambrian.
2. Purple Slates }
1. Conglomerate }
f. Aber and Dinlle fault.

This section is drawn on an east and west line from the Lower Silurian slates of Llefn,* to the neighbourhood of Llys-y-gwynt, about 2 miles S.S.E. of Bangor. Below the Lingula grits and slates (14 and 13), the Cambrian grits (12) crop out, from underneath which, on the west, the ordinary green, "blue," and purple slates (4 to 11) rise towards the surface, obscured by drift; and as they occupy a broad space north of Llanllechid they probably roll to the west in the manner shown in the diagram. Beneath these are the lowest grits, purple slates, and conglomerates (3 to 1) in the bed of the Ogwen. Lower Silurian strata (15) are as usual thrown in by the Aber fault (*f*) against the lowest Cambrian strata of the district. Much of the section is obscured by drift.

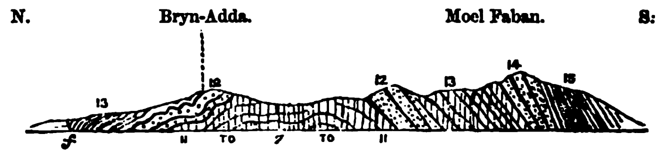
A glance at the map will show that the uppermost Cambrian grit strikes from Bethesda for about 3 miles a little east of north, dipping easterly at an angle of about 45°. It then bends over to the north and west in an anticlinal curve, which, if entire, would form a kind of half dome, but the oval continuation of the grit being thrown down by a north-west fault which passes across Moel Wnion, the purple and green grits and slates abut on the Lingula flags of Fridd-y-Fedw. On the northern side of the anticlinal line, the Cambrian grit, much contorted, occupies a space of about half a mile in breadth, and striking westward about a mile, it abuts on the Lower Silurian beds on the line of the Aber and Dinlle fault, a little south of the third milestone on

* About a mile east of Llanllechid.

the Bangor and Aber road. The arrangement of the rocks is approximately represented in the following diagram, which runs north from Moel Faban across the turnpike road about 3½ miles east of Bangor.

Fig. 63.

SECTION FROM THE BANGOR AND ABER ROAD TO MOEL FABAN.



15. Llandeilo and Bala beds.
14 and 13. Lingula grits and slates.
12. Cambrian grits.
11 to 7. Green, purple, and "blue" slates, which bending over in an anticlinal axis throw in the grits No. 12 on the north, together with a small part of the lowest beds of the Lingula flags 13′, in a triangular space bounded by Jan'rallt. (*See* Map 78 S.E.)
f. Aber and Dinlle fault.

In Nant Francon, the part that corresponds to the Cambrian rocks of the Snowdon section, attains a thickness of about 2,000 feet. The lower part of the strata below Moel-y-Ci being added gives altogether about 3,000 feet, of which from 700 to 1,000 feet consist of slaty rocks, some 300 feet of which are coarse and sandy. In neither section do we reach the base, which is cut off either by the quartz-porphyry or by the Aber and Dinlle fault, but, as far as the beds are known, coarse grits and conglomerates form by far the larger proportion of the series. These coarse beds increase in quantity as we proceed from Nant-y-llef* northwards to Nant Francon,† partly by passage of muddy into sandy and gravelly sediments, and on the whole these coarser sediments must be considered as typical of the Welsh Cambrian strata, both in Merionethshire and Caernarvonshire. In the 8,000 feet of these rocks in Merionethshire there is very little slate, and even the 700 or 1,000 feet of interstratified slaty beds in Caernarvonshire are quite subordinate to the grits and conglomerates.

The capricious variations in the lower part of the Caernarvonshire Cambrian strata, coupled with the presence of so much coarse conglomerate in the lower beds, indicates the existence of land, probably not far off, during their deposition. The structure of this land may be partly inferred from the nature of the pebbles in the conglomerate, which are waterworn, and consist of purple and black slates, quartz rock, felspathic traps, quartz porphyries, and jaspers. The vast thickness of the Cambrian rocks of Merionethshire and Caernarvonshire tells of the waste of a great territory by which the sediments were formed; and furthermore the country from which the pebbles in the conglomerate were derived must have resembled in some respects North Wales as it now stands, but except in these pebbles no trace of that land remains in or near North Wales.

* Map 75 N.E. † Map 78 S.E.

CHAPTER XXII.

The Rocks between Bangor and Caernarvon.

General Description.—It has been already stated (p. 140) that a great fault runs from Aber to Dinlle on the coast of Caernarvon Bay, which throws Lower Silurian strata down on the north-west against the lower parts of the Cambrian beds of Llanberis and the Ogwen. Lithologically these Silurian rocks bear some resemblance to the Lingula beds, but the fossils that have been found in them seem rather to belong to the Llandeilo flags. They are exceedingly scarce, and consist, near the bath-house below Penrhyn Park, Bangor, of a single specimen of *Bellerophon perturbatus*, and on the Seiont opposite Caernarvon of a few indeterminable fragments of a crustacean, and some poor specimens of *Didymograpsus Murchisonæ.* When the country was mapped, the rocks which rise from beneath these strata near Bangor were considered as Cambrian, which, in spite of alteration, they in many respects much resemble. The subject is therefore surrounded with some difficulty, for in Wales the Lingula flags have generally been considered conformable both to the Cambrian and Tremadoc and Llandeilo strata. But from the almost complete difference of species found in the Lingula flags and in the overlying strata, and also because the Llandeilo beds in Ireland lie unconformably on Cambrian rocks, I have been led to believe that the supposed conformity of the Llandeilo on the lower strata in Wales is deceptive.* If, then, the black slaty series of Bangor and Caernarvon are of Llandeilo age, and if the altered rocks of Bangor be Cambrian, then, unexpectedly, about 2,000 feet of the Lingula flags of Nant Francon and Llanberis have thinned away in a space of 3 or 4 miles, or, what is more likely, they have been overlapped by an actual unconformity, for it is exceedingly improbable that Llandeilo fossils go down into the horizon of the Lingula flags. If, on the other hand, neither of these hypotheses be true, the so-called Cambrian rocks of Bangor (and perhaps of all Anglesey) are merely metamorphosed Lower Silurian strata, for the most part or altogether of older date than the Llandeilo beds. I think this, however, so highly improbable, that, coupled with what I know of the *behaviour* of Silurian rocks in Scotland and Ireland, I have scarcely the shadow of a doubt that in the Menai Straits, in Anglesey, and perhaps in Lleyn, the Llandeilo and Bala beds have overlapped the Lingula flags and lie directly on metamorphosed Cambrian strata.

The altered strata near Bangor are for the most part, like the Cambrian strata elsewhere, purple and green in colour, often schistose, chloritic, and frequently conglomeratic. On the whole they dip easterly, and through them, between Bangor and Caer-

* See my Anniversary Address to the Geological Society, 1863.

narvon, there rises a great mass of rock, consisting of a mixture of felspar and quartz, which on Twt hill behind Caernarvon forms a distinct binary compound, that but for the absence of mica would be true granite. Its occurrence is clearly connected with the metamorphism of the adjoining strata, which towards Caernarvon it fairly cuts out, in a manner which I can only explain by the metamorphic alteration of the stratified rock itself beyond the point of fusion when the whole lay deep under ground, during part of the Lower Silurian period.

On the north-west this mass is bounded by a north-east fault running parallel to the Menai straits, and throwing in unaltered Carboniferous limestones, conglomerates, sandstones, and shales against the granitic rock. The conglomerates contain pebbles of the altered rocks, and other neighbouring masses. All the altered rocks of the district were therefore metamorphosed before the deposition of these Carboniferous strata. Indeed I have no doubt but that the alteration was effected before the deposition of any of the Upper Silurian strata, and there is reason for believing that the metamorphism, both of Cambrian and Lower Silurian rocks, took place during the Lower Silurian period itself.

Faults.—Like most of the larger faults of Caernarvonshire, Anglesea, Merionethshire, Montgomeryshire, and Shropshire, this and the other great fault a few miles inland run north-east and south-west, and their courses are exceedingly straight.

Without careful examination the Aber and Dinlle fault might escape detection, and it has sometimes been supposed that the Silurian rocks on its north-west side form a lower series of black shales, dipping under the Cambrian conglomerates of Llanberis. Closer observation, however, shows that in some places the black shales dip away from the Cambrian rocks, as at Llanwnda south of Caernarvon, and at places south of Bangor they dip towards them, and further, many of the Cambrian and Silurian beds strike more or less at each other. These circumstances led Mr. Selwyn first to infer the existence of this fault, an inference corroborated by myself, when in mapping the details of the Cambrian strata I detected the northern and westward curve of the grits and purple slates north of Llanllechid, and their disappearance in the line of fault at a point where, following the strike, if not cut off, they ought to be found trending towards Llandegai.* As already stated, still further proof was obtained by the discovery of Lower Silurian fossils in the black shales near Caernarvon and Bangor.

These Silurian rocks are, however, a little different from the ordinary type in North Wales, owing partly to differences in original material, partly to less thorough consolidation of the rock, and the comparative absence of cleavage. These give to the Silurian beds between Bangor and Caernarvon more of a shaley than a slaty texture.

This repetition of these Silurian beds being admitted, it becomes apparent that the present structure of the country is the result of the denudation of a faulted anticlinal curve in the manner shown near the river Rothell in fig. 3, pl. 58, and in diagram, No. 55, p. 149. More perfect relics of this bend are found in the arch of Cambrian and Silurian rocks north of Bethesda,† the side of which (on the north-west) has been cut off by the same fault. The arrangement of the Lingula beds affected by this arch between Moel-Wnion and Maes-y-gaer, near Aber, is so very remarkable, as a piece of physical geology, that I shall give a special description of it, by the help of the map (fig. 64). The same coarse grits with the overlying slates are repeated five times

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* A mile S.S.E. of Bangor.

† *See* Map 78 N.E.

in compartments formed by five north-west faults that intersect the country between the Dinlle and Aber fault and that which runs between the Aber river and Bryn-Efail. In each compartment the grits lie in the form of solid half cones, marked *a, b, c* (fig. 64), or of parts of cones, as in *d, e,* in the following diagram:—

Fig. 64.

MAP OF THE COUNTRY BETWEEN ABER AND BETHESDA.

h. Purple Slate } Cambrian.
g. Grit }
f. Lingula Flags }
a. b. c. d. e. Lingula Grits } Silurian.
s. Llandeilo and Bala beds }

The shaded space *h* represents the blue and purple slates, and the dotted bands *g* the Cambrian grits of Bryn Addu and Bethesda that overlie them. The blank portions *f* represent the Lingula slate; the remaining dotted spaces *e'* stand for the Lingula grits; and *s* shows the place of the Silurian beds above that horizon. The cause of the peculiar arrangement at the surface of the Lingula grits *a, b, c, d, e*, and of the overlying slates, must be owing to the whole mass having sloped downwards in an underground pointed anticlinal form, somewhat like half a cone, the apex of which was directed to the north-east, and different sections of it had been shifted and heaved up and down as it were in stages to certain levels between Woel-Wnion and Maes-y-gaer by four faults, the form of the ground having since been modified and the grits exposed by denudation. The whole must be looked on simply as the shattered continuation of the great broken curve, the anticlinal axis of which passes Maes-y-gaer near Aber, through Llanllechid and Moel-y-Ci, towards the entrance of the Pass of Llanberis.

If we attempt to restore the curve above alluded to, we get approximately the amount of the throw of the Aber and Dinlle fault in places where, like those crossed by the Snowdon and Glyder-fawr sections * the data are tolerably perfect. To approach accuracy in this estimate certain considerations must be attended to.

It is plain that the quartz-porphyry of Llyn Padarn is of later date than the Cambrian rocks, for the reason that they pass into it by metamorphism. It will in another place be shown that this alteration was probably of Lower Silurian date, but in no sense were masses of porphyry, like that of Llanberis, the cause of the faults and contortions of the Cambrian and Silurian strata, for they themselves partake of the contortions and are affected by the faults. The curves, for instance, of the beds of conglomerate and slate on Clegyr above Llyn-Padarn, spread half across the porphyry, and other like cases, give obvious hints that the molten mass was not protruded vertically like a great dyke, but rather that part of the strata once spread closely across its present surface, perhaps somewhat as it now stands. If so, then by restoring the denuded strata in a broad anticlinal curve in the manner shown by the dotted lines west of Dinas (Section 3, Pl. 28), we shall find that the Silurian beds have probably been thrown down on the north-west about 2,000 feet; and if we apply the same sort of measurement to the Glyder-fawr section (No. 2, Pl. 28, Horizontal sections, sheet 31) only 4 miles off the throw increases to between 4,000 and 5,000 feet. If the Bangor and Caernarvon Silurian beds be Llandeilo flags or Bala beds, and if there be unconformity between these and the Lingula flags and Cambrian strata, so that the former are overlapped, then in both places the fault may be still approximately of the same amount.

North-west of the fault grit is mingled with the Silurian shales, but it has nowhere been found to lie in one long band at the top of the Lingula flags, like that which runs from the Pass of Llanberis to Aber.

Much of the shale is black, ferruginous, and micaceous, but the rocks of the country are much concealed by drift. A short section is exposed between Llanddeiniolen and Dinas Dinorwig. A tolerable section is also seen at Caernarvon Castle, and here and there on the banks of the river Seiont as far up as the turnpike bridge. The rocks there consist of black and dark brown slaty micaceous shales with occasional sandy beds, sparingly fossiliferous (p. 161). A greenstone dyke lies in the line of bedding by the bridge and hardens the strata at the points of contact. Similar black shales were proved under the drift in a search for coal in the year 1848 between Coed-mawr and Pentre Seiont by the misdirected industry of certain speculators led by a "practical man," himself misled by the black shaley character of the rock and the wetness of a soil fertile in rushes, like many of the true coal-measure shales.

Metamorphic Cambrian Rocks.—At a point immediately west of the Penrhyn Arms at Bangor metamorphic Cambrian rocks rise from under undoubted Silurian strata. The boundary strikes about S.S.W. to Cefn-mawr, and from thence south-west to the neighbourhood of Llanddeiniolen. Along this line the overlying Silurian beds at their base consist of fine dark grey slaty micaceous

* Six-inch Sections, Sheets 28 and 31.

grit, very hard and altered, and so broken up by innumerable joints crossing each other irregularly that it is almost impossible to obtain a clear fracture. The best sections of both occur near Bangor.

The reasons that induced Mr. Selwyn and myself to consider the underlying metamorphic rocks as altered Cambrian were as follows* :—

It has been shown that in places the Cambrian rocks † have been much altered near the quartz-porphyry. This alteration becomes so decisive in Glynllifon Park and its neighbourhood (Map 75 N.W.) that it is difficult to separate quartz-porphyry from altered grit, the felspathic base of the stratified rock often giving the impression that it has undergone absolute fusion like some of the rocks of Llyn-Padarn. If the rock were well exposed, probably every stage between porphyry and grit might be observed, between the western side of the porphyry and the sea. Much of the altered strata between Bangor and Llanddeiniolen greatly resembles the Cambrian rock of Glynllifon, and this, taken in connexion with the north-western downthrow of the Aber and Dinlle fault suggested that the Bangor rocks were a repetition of the Cambrian strata in a highly metamorphosed condition.

In 1854 I described these rocks near Bangor (Horizontal sections, sheet 31) as "green and purple grits, conglomerates, and slaty beds, generally much "altered. * * * They are hard and flinty, of a chloritic green colour, "fracturing with small irregular joints often coated with chlorite." Good local sections may be seen along the shores of Menai Straits south-west of Garth Point,—in the turnpike road and field quarries south-west of Bangor,—on the hills east and south of the town,—and in parts of the grounds of Perfeddgoed. In all these places the slaty beds are hard and splintery, sometimes purple, but generally of a chlorite green colour. The grits are often of the same hues, and granularly crystalline like those of Glynllyfon Park, and the bedding, especially near the igneous rock, is obliterated. Above the town, the cliffs, without close examination, might be mistaken for trap. The structure of the conglomerates that form part of these rocks was well shown in the heaps of rubbish thrown out at the mouths of the shafts that were sunk during the formation of the railway tunnel. Like those of Llanberis and Moel-y-Ci, they consist of rounded pebbles of quartz, quartz-rock, felspar-porphyry, quartz-porphyry, purple sandstone, blue and black slate, and green and red jaspar; and as I do not know such a conglomerate in any of the Silurian strata of Caernarvonshire, while it occurs plentifully in the lowest Cambrian rocks, it gives another reason for considering the Bangor beds as of that age.

Other Strata on Menai Straits.—There is but little to add respecting the rocks of this part of Caernarvonshire.

A triangular patch of black sandy micaceous Silurian shales occurs at Bangor, let into the midst of the metamorphic strata by two faults, and bounded on the north-east by the sea. These faults probably join near the railway station, and seem to continue in one line for several miles along the straight valley through which the Caernarvon road passes. Another great north-east fault, already alluded to (p. 162), cuts off the whole Silurian and Cambrian series from the neighbourhood of Garth point, Bangor, to Caernarvon, throwing down on the north-west rocks of the Carboniferous series (Section 3, Pl. 38).‡ These lower Carboniferous rocks, coloured blue in the map, are partly of the ordinary limestone type, but a great proportion of them are composed of shales, yellow sandstones, and quartz conglomerates more or less calcareous. They were probably formed in a sea, comparatively shallow, not far from shore. Under the limestones at Menai bridge, beds of deep red marl occur associated with quartz-conglomerates, and the other beds with which they are associated seem to indicate that they belong to the Carboniferous series. Indeed throughout the Carboniferous rocks of Caernarvonshire and Anglesey red beds are not uncommon, for on the shores of the Menai between Caernarvon and Llanfair-is-gaer, and on the opposite shore between Menai-fron and the ferry house, there are red marls so bright in colour that they were originally mis-

* This ground was chiefly mapped by Mr. Selwyn.
† Two miles south of Caernarvon.
‡ Maps 78 S.W. and S.E., and Horizontal Sections, sheet 28, line 1.

taken for New red marl by persons not minutely acquainted with the structure of the neighbourhood.*

Underneath them at Llanfair-is-gaer there is a mass of conglomerate of a shingly and beach-like character, more particularly described at page 200.

Igneous Rocks.—The crystalline rock associated with these metamorphic strata consists principally of mixed felspar and quartz, sometimes well crystallized. Apparently there is in it more free silica than in the Llyn Padarn porphory. Its lithological character, as a whole, is intermediate between the quartz porphyry of Llyn Padarn and the granite of Anglesea.

Three masses of greenstone are intruded into the shales south and south-west of Caernarvon. The principal one, more than a mile in length, lies between Llanfaglan and the tram-road. It is one of the most beautiful greenstones in Wales, and consists of finely developed crystals of felspar and hornblende with a little iron pyrites. Some of the crystals of hornblende are more than an inch in length.

Several dykes pierce the carboniferous rocks of the Menai Straits near Llanfair-is-gaer.

CHAPTER XXIII.

The Rocks of Lleyn, or the Promontory between Caernarvon Bay and Cardigan Bay.

General Description.—Although the rocks of Anglesey are both stratigraphically and lithologically continuations of those on the Caernarvonshire side of the straits, it will be convenient first to describe the district of Lleyn, because of its more direct union with the country described in last chapter.

Like that area it consists of metamorphic rocks, supposed to be Cambrian, and of Lower Silurian strata, through which there rise numerous bosses of greenstone and syenitic rocks, some of them of great extent, and in Yr Eifl or the Rivals, Carn Boduan, Mynydd Mynytho near Llanbedrog, Mynydd-y-Rhiw, and other heights, often rising through the covering of drift, and forming the loftiest hills of the district. The stratified rocks generally lie low, and except on the coast cliffs they are mostly so obscured by drift that it is difficult to make out the details of their stratification. In the main, however, they are arranged in a rude synclinal curve which is a broken continuation of the great Silurian basin of which Snowdon forms the centre, between the Cambrian grits of Merionethshire and Llanberis. Viewed in this light the grits and shales that form the promontory south of St. Tudwal's Road are, in the opinion of Mr. Selwyn, a faulted continuation of the Harlech grits, the upper boundary of which strikes westward out to sea through Morfa Harlech, near Llanfihangel-y-traethau (Map 75 S.E.), and reappears crossing the promontory between St. Tudwal's Islands and Hell's Mouth. (Map 75 S.W.) This fragment, through broken, still dips northward, and, it is supposed, passing under a belt of Silurian rocks about 7 miles broad, reappears in the metamorphic form of chlorite and mica schists on the

* For further remarks on this subject see pp. 199 and 200.

north-west coast between Bardsey Island and Porth-dinlleyn. (Map 75 S., N. and 75 N.W.) There, probably faulted, it runs out to sea north easterly, trending towards the boundary between Silurian and Cambrian rocks that strikes in a south-west direction from Llanberis, and passes into Caernarvon Bay near Clynnog-fawr.

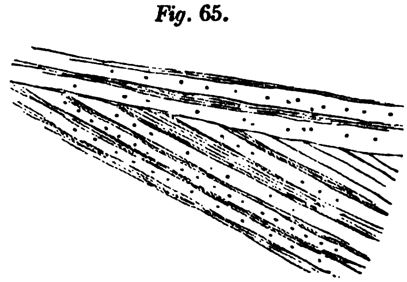
The Silurian rocks of the whole area west of Traeth-Mawr, from position and the evidence of fossils, consist, as far as known, of Lingula flags, Tremadoc slates, Llandeilo flags, and Caradoc or Bala beds. The unbroken continuity of the boundary lines south of Llanberis sufficiently indicates the position of the Lingula flags near Clynnog-fawr (75 N.W.), but even if the drift were removed, it is very improbable that they should be found adjoining the Cambrian rocks between Nevin and Aberdaron. West of Tremadoc the Lingula flags and overlying strata have been already described, and at Llanfaelrhys, near Aberdaron, a meagre list of fossils seems to point to a low part of the Llandeilo flags. They are *Ogygia Selwynii*, and another tail of the same genus, a *Lingula* like *attenuata*, another broader species, *Didymograpsus Murchisonii*, and numerous specimens of *Graptolites sagittarius*. There is reason to believe that the same strata on the south side of the synclinal curve are faulted against the supposed Cambrian grits of St. Tudwal's, while Caradoc or Bala beds form the main mass of the country, fossils of many of the usual species having been found near Pwllheli, Boduan, Llanystumdwy, and other places.

The igneous rocks of the area, unlike those of Snowdon, are not interbedded with the strata, very imperfect examples of bedded ashes occurring alone in one case near Pwllheli. The rest may be briefly described as bosses surrounded by altered strata. Some are felspar porphyries, others are syenitic, and almost granitic in texture, and others of greenstone, in some of which hornblende and in others felspar predominates. Occasionally they pass into each other.

The following details may be found locally interesting.

Cambrian Rocks, Penrhyn-du.—On the coast cliffs between Penrhyn-du and Mynydd Cilan, magnificent sections occur to the so-called Cambrian strata. Between Trwyn-y-ffosle on the west and Pared-mawr in Porth Ceiriad, the beds undulate eastward at angles between 20° and 40°, and consist of thick-bedded, hard, brown, coarse and fine sandstone, grit, and quartz rock, mingled with a little fine conglomerate. They are often micaceous and sometimes felspathic, and are interstratified with blue and dark grey shale sometimes almost black. In a little bay at the base of Trwyn-llech-y-ddol there is an appearance of unconformity in some of the beds,

Fig. 65.



but it may be merely a case of false bedding. On Pared-mawr black slaty beds predominate mingled with thin grits. Having been denuded between the hard headlands of Trwyn-llech-y-ddol and Trwyn-yr-wylfa, the bay of Porthceiriad is the result. At the south end of Penrhyn-du near Pistyll-cim similar beds are interstratified with green bands and red patches of a species of jasper-like rock sometimes lying in minor layers which are twisted and contorted somewhat like the semi-metamorphic Cambrian strata of the South Stack of Holyhead Island.

An east and west fault runs from Pistyll-cim to Trwyn-y-ffosle, north of which the strike suddenly changes, and similar beds with slight undulations dip northerly at angles that vary between 15° and 30°. St. Tudwal's Islands are formed of the same rocks, dipping north-westerly at angles ranging between 20° and 40°.

There is difficulty in identifying these beds with the undoubted Harlech grits, in consequence of the east and west fault which brings them against the Silurian beds between St. Tudwal's Road and Porth Nigel or Hell's Mouth, and also that in some respects they differ in lithological character.

Mr. Selwyn has described the strata of this promontory generally as "thick "and thin bedded hard light grey silicious grits, interstratified with dark blue "gritty shales;" and again as "hard gritty brown and grey sandstones with hard blue and grey micaceous slates,"* and the Cambrian rocks of Barmouth and Harlech as "hard greenish grey quartzose sandstone (grits) and con-"glomerates with beds of dark blue and purplish blue slate, the grit often "very felspathic and semi-crystalline;"† and again as "thick beds of hard "grey and greenish grey quartzose sandstone, grit, and quartz-conglomerate, "with beds of blue, green, and purple argillaceous slate. The sandstones are "often partly formed of slightly water-worn grains of crystalline quartz and "felspar, the quartz generally greatly predominating." If these are the true equivalents of the rocks of the promontory of Penrhyn-du, there is thus a great difference between them in lithological character, for the grits of Harlech are greener, and contain beds of green and purple slate, whereas the slates of Penrhyn-du are grey and blue, a difference scarcely to be expected, considering the general constancy of colour in the Cambrian rocks of Wales, those of Merionethshire closely resembling those of Llanberis, and the same resemblance might be expected in the rocks at St. Tudwal's Road.

When first visited by Sir Henry De la Beche, he considered them more like the Denbighshire grits than any other strata with which he was acquainted. If they are equivalents, then the Wenlock beds must have overspread this country and circled into Cardigan Bay, and this is by no means an improbable hypothesis. I have several times visited the district, and at one time felt inclined to consider them the probable equivalents of the Lower Llandovery gritty series that occupies great part of the coast of South Wales between Aberystwyth and Dinas Head near Fishguard, for the following reasons:—

Near Aberaeron and Aberystwyth, in Cardiganshire, the rocks consist of beds of thick and thin hard grey sandstones interstratified with dark coloured slates, and the neigbouring dark Llandeilo slates of North Pembrokeshire are pierced by igneous bosses like the rocks of Lleyn. The kind of scenery is the same in both the districts that respectively form the north and south horns of Cardigan Bay, and this resemblance is owing to the hardness of some and the softness of other rocks in both areas, which have thus unequally resisted denudation. The Cambrian rocks of North Pembrokeshire also are purple, like those of Merionethshire and Llanberis, and all these resemblances led me to compare the St. Tudwal's grits with the grits that form great part of the coast of Cardigan Bay from Aberystwyth to Dinas Head, near Fishguard. In spite, however, of these resemblances, I attach much weight to Mr. Selwyn's opinion, that they probably belong to the Cambrian series; 1st, because though well searched no fossils have been found in them; 2nd, because they lie in the strike of the Harlech grits where they last run out to sea; and, 3rd, because there are no great masses of grit at all like them anywhere in the Lower Silurian rocks of Caer-

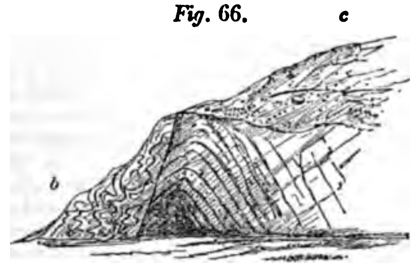
* MSS. † Six-inch Sections, Sheet No. 26.

narvonshire, unless it be that some of the Lingula grits of Llanberis slightly resemble them. The Lingula flags, however, thin out rapidly to the west, and are altogether absent in the corresponding longitude of Anglesey; and though, in the absence of fossils and the existence of the fault that runs west from Porth-bach, it is impossible to assign the rocks of Penrhyn-du positively to any horizon, yet perhaps Mr. Selwyn was in the right when he considered them as belonging to the series of the Harlech grits.

Cambrian Rocks between Bardsey Island and Nevin.

On the north-west side of the synclinal curve, the Cambrian rocks form a band (exclusive of Bardsey Island) 14 miles long from Bardsey Sound to Nevin, and generally from a mile to two miles wide. A long spur proceeds southward from the main mass to the east coast of Aberdaron Bay. On this promontory, on the west, there are beds of "green chloritic siliceous schists," against which abut beds of "dark blue and grey banded micaceous sandstones "and blue shales. At the junction with the green schists they are much "contorted, and apparently dip against them"* in a manner that indicates a fault.

Fig. 66.



a. Chloritic Schist.
b. Silurian Shales, &c.
c. Drift.

On the coast nearer Aberdaron the junction is obscured by drift, but above Bodwrdda the Silurian beds strike towards the schists, dipping south-west about 40°, and this, with the occurrence of springs along the boundary line, denotes that a fault also forms the western edge of this spur of schistose strata.

Beds of sand, clay, and gravel still conceal much of the Silurian rocks, from Mynydd Ystum, north of Aberdaron, to Parwyd Bay; but wherever dips are seen (as at Parwyd) it is evident either that Lower Silurian rocks (newer than the Lingula flags) lie unconformably on the Cambrian schists, which is not improbable, or else that they are faulted against them. It is an exceedingly disturbed country, and the evidence is in favour of the last supposition, for the Silurian rocks strike obliquely towards the schists, which would not be the case if they merely lay unconformably upon them; for though the Cambrian rocks and Lingula flags may probably have been disturbed together before the deposition of the Llandeilo and Bala beds, yet when these last were also disturbed the movement must have affected both sets of rocks, so that, under these circumstances, though the lower strata may strike towards the base of the newer formation, it is exceedingly unlikely that the base of the newer strata should strike towards the lower beds on which they lie unconformably.

It is probable that the long straight boundary line south-west from Nevin, on the north side of the promontory, may not also be a fault. The drift is so great that the evidence is imperfect, though sufficient to show that the line, as drawn by Mr. Selwyn, is, as nearly as may be, correct.

Bardsey.—The east coast of Bardsey Island consists of "green, grey, and "purple siliceous schists and slaty rocks, patches of quartz rock, and a few

* MS., A. R. Selwyn.

" thin grey calcareous bands, all much contorted on a small scale, without " affecting the general north-westerly dip."* A lenticular piece of marble occurs on the coast about half way between Ogof-Morlâs and Pen Cristin. At Bay-y-Nant the dip is easterly. On the west the rocks are of the same description. The whole undulates in various contortions.

The Mainland.—From Bardsey Island to Nevin Mr. Selwyn describes the rocks as " chlorite and mica schists. A series of green, grey, and purple schists, " often very hard and siliceous, sometimes arenaceous and gritty, with large " and small veins, beds, and masses of quartz-rock, also bands and patches of " calcareous rock and grey and pink siliceous crystalline limestone, occasionally " burnt for lime." These are pierced " by numerous greenstone dykes, and " contain patches of serpentine and veins and nodules of red jasper. These " beds are much contorted on a small scale, but their general dip is north- " westerly from 25° to 50°."† The small contortions alluded to are those little foliated twistings of quartz, micaceous, chloritic, and less altered sediment, so characteristic of many metamorphic rocks. Quartz veins on a large scale not in lines of foliation also often intersect the rock in all directions. Minute descriptions of many special places would scarcely convey more information.

On the mainland in and about Porth-felen there are " beds of greenish " grey, brown, and purple schists, mostly more or less calcareous, asso- " ciated with short veins and patches of red and white marble, intermingled " with veins and lumps of red jasper." These also are very siliceous and highly metamorphic. Between this and Braich-y-pwll the schists are exceedingly felspathic, and in some places almost like hornstone. They are full of veins and strings of quartz. By Porth-llanllawen and for some distance inland purple beds are common, not unlike the recognized Cambrian purple slates of Llanberis.

Purple and white calcareous rocks, with veins and masses of red jasper, occur a little south of Dinas-oedd ; and again, purple and pink limestone, full of veins of white carbonate of lime and patches of red jasper, in Borth-oer and at Morfa-trwyn-glas. They are associated with green and purple schist and slaty and quartzose beds. Intermingled with these at Trwyn-glas are short lenticular beds and nodules of quartz rock, and the same kind of phenomena may be seen along the coast by Porth-y-gwylan and Rhos-hirdref. At Porth-wen, on the west side of the promontory of Porth-dinlleyn, they have been described by Sir Henry De la Beche‡ as " hard siliceous beds, mingled with slate, occasionally micaceous." The general strike is about N.N.E. They are irregularly waved and crumpled, but the beds, as a whole, are nearly vertical. Between Edeyrn and the sea they dip north-west. Many trap dykes, principally of hornblendic greenstone, pierce the strata between Porth-dinlleyn and Porth Penllech to the south-west. They are also numerous about Porth-ferin, and occur at many other points of this coast and around Bardsey Island.

" The rock at Porth-dinlleyn§ is a kind of coarse green and purple serpentine, with nests of red jasper. Veins of the serpentine are observed to " dash in amid " the slaty series at Porth-wen." Fourteen or 15 other patches of serpentine or serpentinous rock appear amid the schists to the south-west. Several of these are exceedingly small, and there is reason to believe that they are interstratified or largely interlaminated with the schists in such a manner that they must be considered as the result of metamorphism of siliceous and magnesian materials that formed portions of the stratified deposits. A good example of interlamination occurs at Careg, about 2 miles N.N.W. of Aberdaron, where streaks of lime, serpentine, and schist alternate with each other, more especially on the slope towards the sea. Neither is there anything in this opposed to Sir Henry De la Beche's expression that veins of this rock are observed to " *dash in* amid the slaty series," for such metamorphisms occurring at great depths, it

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* All the quotations are from MS. notes by Mr. Selwyn except where the contrary is mentioned. The district was entirely mapped by him.

† Selwyn MS., on original copy of Map 76 S.

‡ MS. note.

§ Sir Henry De la Beche's MS. notes.

is easy to understand how certain portions of the strata that attained an absolute fusion under the united influences of moist heat and new chemical combinations, might be injected into any fissures that might be formed in the adjacent less altered strata.

Silurian Rocks.—The Silurian rocks of Lleyn, though associated with numerous masses of igneous rocks, are never metamorphosed like the Cambrian rocks of the district, but resemble the ordinary Lower Silurian strata of the rest of North Wales. Buried, however, in general, under deep superficial beds of stratified sand, gravel, and boulder clay, it is impossible minutely to connect the country with the sub-divisions into which the rocks of Merionethshire and other parts of Caernarvonshire resolve themselves. Even the igneous rocks elsewhere, assisted in determining horizons by their interbedded character, but in Lleyn they are almost all intrusive, and afford no clue to the dissection of the country like the widely extended ashes of the two stratigraphical horizons of Cader Idris and Moelwyn, and of Snowdon. Nevertheless, if it be true, as Mr. Selwyn and myself suppose, that the igneous mass of Llwyd Mawr represents the felspathic porphyry of Moel Hebog (diagram No. 49, p. 137), then the blue and black slates that rise from under it on the north-west must represent the Caradoc or Bala and Lingula beds immediately west of Snowdon and Moel Hebog (Map 75 N.E.), and their position in relation to the Cambrian strata north of Clynnog-fawr proves it. It is also worth notice that the same kind of bedded iron ore that occurs near Tremadoc in the lower Tremadoc slates, and above Bettws Garmon is found in Trwyn-y-tâl, on the north coast near Yr-Eifl, and it is probable that they are equivalent strata. The fossils found in the interior of the promontory prove the rocks to be chiefly equivalents of the Bala beds, a circumstance consistent with the idea of their forming a rude synclinal curve, and this conclusion is further aided by the circumstance that between St. Tudwal's Road and Porth Nigel (Map 75 S.W.) there are dark blue slates and brown sandy beds, highly disturbed and faulted against the supposed Cambrian grit, which, from their character, and the occurrence in them of pisolitic iron ore at Llanergan and Abersoch, renders it probable that they also belong to the Tremadoc beds.* The general dips are northerly, and though somewhat obscure, there is little doubt that they dip under the Caradoc or Bala rocks near Llanbedrog.

Turning to the Lingula flags of Tremadoc and Traeth Bach, where the promontory joins the mainland (Map 75 N.E. and S.E.) it might at first sight be supposed that the western strike of the beds would prolong them into the heart of Lleyn; but before reaching Criccieth (75 S.W.) the strata begin to undulate, and the whole of the Lingula beds appear to be cut off by the great north and south fault (the precise line of which it was impossible to determine) that passes down the valley east of Llwyd Mawr, and near Criccieth throws the Bala beds and Lingula beds against each other. North of Criccieth the west boundary of the Llwyd Mawr porphyry is entirely hidden by drift, but so sharp is the bend at the north-west angle near Pant-glas, that Mr. Selwyn ventured to consider the western boundary line as a probable fault, an idea in which I agree, for otherwise it is improbable that the Silurian strata north-west of Llwyd Mawr, pent up in the space of little more than a mile, at so high an angle, between the Cambrian rocks and the porphyry, should so suddenly expand and fill the whole promontory of Lleyn. This they do by undulations of strata, which appear to be the lithological equivalents less of the unfossiliferous slaty rocks above the Lingula beds of Llanberis than of the fossiliferous strata that encircle the interbedded porphyry of Moel Hebog.

The places where fossils have been found are as follows, taken approximately from east to west. Most of them were found by Mr. Selwyn, assisted by Mr. Richard Gibbs, and the lists were drawn up by Mr. Salter.

Near Yyns-galed on the road to Plas Llecheiddior (2½ miles west of Dolbenmaer) some brownish yellow sandy beds crop up for a few yards from under the

* These iron ores may, however, be on different levels, for the ore of Tremadoc is near the top of the Lingula beds, and that of Cader Idris immediately underlies the calcareous ashes 6,000 feet above the Cambrian rocks, whereas at Bettws Garmon it cannot be more than 1,000 feet from the junction. This may, however, be partly due to thinning out of the strata.

drift. They are considered by Mr. Selwyn to be the equivalents of the Boduan beds, and are very fossiliferous, yielding—

Crustacea.

Calymene brevicapitata (the same variety that is found at Bala, with short *glabella*)	12
Trinucleus concentricus	22
Asaphus Powisii	5
Illænus Bowmanni	6
Phacops conophthalmus	6
Beyrichia complicata	2
Tentaculites annulatus (*with close rings*)	2

Mollusca.

Leptæna sericea	14
Strophomena grandis	35
Orthis elegantula	70
Ctenodonta	2
Murchisonia scalaris	12
Scalites	11
Bellerophon Murchisoni, D'Orb.? / *B. striatus*, Sow.	25
B. bilobatus	6
B. dilitatus	2
Pterotheca	12
Petraia elongata	5
Cleidophorus like *antiquus*	4
Ctenodonta levata (Hall)	1

Further south, near Plas-hen, one mile north-west of Llanystumdwy, there were found in a black rotten slate—

Homalonotus bisulcatus	3
Trinucleus concentricus	3
Orthis elegantula	50
Lingula, sp.	20
Ctenodonta ?	2
Pleurotomaria	6
Bellerophon (*bilobatus ?*)	4

Immediately north of Pwllheli, in fine ferruginous slaty sandstones near Pen-'r-allt, and also by the turnpike near Tan-'r-allt, the following fossils were found:—

Trinucleus concentricus	18
Homalonotus bisulcatus	11
Phacops apiculatus	9
Beyrichia complicata	5
Tentaculites annulatus	4
Leptæna tenuistriata	2
L. sericea	17
Orthis elegantula	100
O. calligramma var. *virgata*	1
Lingula ovata	1
Ctenodonta	2
Murchisonia scalaris	1
Pleurotomaria lenticularis	1
Bellerophon bilobatus	8
Stenopora fibrosa	2

At Pont-rhyd-hir, about 1½ mile west of Pwllheli, there are black ferruginous slates passing into gritty beds containing crystals of felspar. They contain—

Homalonotus bisulcatus	5
Cybele verrucosa	2
Trinucleus concentricus	3
Asaphus Powisii ?	1
Orthis elegantula	1
Stenopora fibrosa	2

Above Crugan, about half way between Llanbedrog and Penrhos, there are beds of blue shale with calcareous nodules. They contain—

Asaphus Powisii	1
Calymene Blumenbachii	3
Trinucleus concentricus	2
Petraia elongata	1

West of Llanbedrog and the felspar porphyry of Mynydd-tir-y-Cwmmwd (5 miles south-west of Pwllheli) in beds of sandstone and arenaceous slate dipping northerly at angles of about 30°, there were found—

Crustacea.

Calymene Blumenbachii	2
Homalonotus bisulcatus	8
Asaphus Powisii	2
Proœtus latifrons	1
Trinucleus concentricus	14
Phacops (*Odini*) *conopthalmus*	16
Lichas laxatus	6
Cybele rugosa	2
Tentaculites annulatus	1
Leptæna tenuistriata	2
Orthis calligramma var. *virgata*	30
O. elegantula	10
Strophomena spiriferoides	6
Ptilodictya dichotoma	1
Favosites fibrosa	8
F. var. *ramulosa ?*	12
F. var. *Lycoperdon*	5

North-west of Boduan there are beds of coarse felspathic breccia passing rapidly into brown gritty sandstone, the latter containing—

Encrinurus punctatus?	1	*Leptœna sericea*	4
Orthis flabellulum	100	*Rhynchonella*, sp.	1
O. elegantula	10	*Turbo crebristria*	1
Strophomena grandis	16	*Encrinite stems*	10

Orthis flabellulum is found here in finer condition and in greater numbers than in any other locality.

Round the felspathic porphyry of Y-garn-bach, near Madryn, there are blue fossiliferous shales, and a little further sandy ferruginous slates, probably nearly equivalent to the Boduan beds. They contain the following fossils:—

CRUSTACEA.

Trinucleus concentricus (*Caractaci*)	6
Phacops apiculatus, Pl. fig.	16
Homalonotus bisulcatus, Pl. fig.	10
Beyrichia complicata	14
Tentaculites annulatus	8

BRACHIOPODA.

Lingula sp.	1
Orthis elegantula.	
Leptœna sericea, some specimens with striæ nearly equal all over	20
Strophomena grandis	17
S. depressa or *tenuistriata*	3

RADIATA.

Encrinite stems, a few.	
Stenopora fibrosa, var. *Lycoperdon*	5
S. var. *ramulosa*, Phil.	4

found in a fine slaty sandstone with much protoxide of iron.

The dark slates and thin flaggy beds of Llanfaelrhys dip towards and perhaps under the greenstones of Porthllawenan and Mynydd Pen-ar-fynydd. There were collected in them by Messrs. Selwyn and Gibbs—

Asaphus Selwynii	2	*Graptolites Murchisonii*	2
Lingula	7	and others.	

At Parwyd Cove, south-west of Aberdaron, there are beds of slate, grit, and conglomerate, dipping under the greenstone of Pen-y-Cil at angles varying from 30° to 80°. In these Sir Henry De la Beche found only—

Stenopora fibrosa, the narrow-branched variety, and *Encrinite* stems.

They probably belong to the Bala series.

Igneous rocks.—It now only remains to notice the igneous rocks of the promontory. These I shall describe from east to west. They are all of the kinds usually called intrusive.

Cricceith castle stands on columnar felspathic trap, and similar rocks are exposed by a partial removal of the drift at four neighbouring places, viz., Y-graig-ddu, Mynydd Ednyfed, Dynana, and Plas-hen. The rock of Mynydd-y-cennin is quartz porphyry, similar to that of Llyn Padarn near Llanberis, and probably having a like origin, small granular crystals of quartz being set in a felspathic base. The rock of Bwlch-mawr near Clynnog-fawr is more easy to describe than to name. It consists of white or pale yellow crystals of felspar set in a base, probably formed of a mixture of felspathic and hornblendic matter, unseparated by crystallization. By some it might be called a species of greenstone, by others a felspar porphyry. On Y-Gyrn-goch the rock is syenite, compounded mainly of felspar, mingled with a little quartz and minute quantities of hornblende. Further west, on Moel-Penllechog, it becomes still more syenitic and crystalline. The rock that forms the magnificent cliff of Trwyn-y-gorlech is mostly a kind of greenstone, compounded of small crystals of hornblende and felspar in equal proportions. Sometimes free silica appears, and then it becomes a syenitic rock speckled with horblende. It is largely quarried for paving stones. There is a well-crystallized greenstone half a mile south-west of Clynnog-fawr, and also on Pen-y-gaer and Carn Pentwrch, south of Bwlch mawr. The neighbouring bosses are more felspathic. The graceful peaks of Yr-Eifl (or the Rivals) consist of falspar porphyry, often very syenitic. On the south coast the rock of Pen-y-chain is felspar porphyry, in some places completely charged with agate nodules. These are well shown on the coast. The boss that lies between it and Abererch is greenstone, and in places a felspathic porphyry. Careg-y-rimbill (the gimblet rock) is a small-grained greenstone in

which the hornblende rather predominates over the felspar. It is the principa building-stone of the neighbourhood. North and north-east of Pwllheli, as far as Plas-du, there is a broad strip of rock, in two places alternating with slaty bands. It hovers in character between a greenstone and a felspar porphyry. At the trigonometrical station it consists of large crystals of felspar imbedded in a hornblendic-looking base. Associated with this rock, about three-quarters of a mile west of Pwllheli, there occurs the only rock in Lleyn of an ashy or brecciated character. It is well stratified, and consists of small felspathic fragments, green grains, and broken crystals. Specks of slaty matter occur in it. The Boduan rocks, which stretch up to the coast north-east of Nevin, are principally light coloured very felspathic greenstones. About 6 miles west of Pwllheli, around Llanfihangel Bachellaeth, and Llanbedrog, there is a great mass, about 6 miles in length, consisting of felspar porphyry, which when a little weathered exhibits pale yellow felspar crystals imbedded in a brown felspathic base; when fresh it is blue. The little boss of Careg-y-defaid, a mile north-east of Llanbedrog, is a sort of felspathic hornstone porphyry enclosing agate nodules. Another mass of great size lies about half way between Llanbedrog and the western extremity of the promontory of Lleyn. It stretches from Trwyn-talfarach near Llanfaelrhys to the Cromlech near Penllech, and is principally composed of varieties of greenstone on Penarfynydd, Mynydd-y-graig, and Mynydd-y-rhiw, but further north and west of Mynydd-y-rhiw it passes into syenite.

Between the neighbourhood of Llanfaelrhys and Porth-lleiddiad the greater part of the cliffs consist of greenstone. North of Porth Cadlan this patch is more than half a mile in width. A strip of greenstone runs along the west side of Aberdaron Bay between Pen-y-cil and Porth-meudwy, and another small patch occurs on the north side of that little harbour.

Wherever any of these are seen in contact with the Silurian strata, the latter are found to be altered (baked) at the junction; but the change usually extends a little way, and is not to be confounded with those greater metamorphic processes which, as in the neighbouring Cambrian rocks, are attended with a foliated re-arrangement of their constituents, and obliteration of their original lithological structure.

CHAPTER XXIV.

ANGLESEY AND HOLYHEAD.

General Description.—The chief stratified rocks of Anglesey and Holyhead are, in descending order,—

Permian,
Coal-measures,
Millstone grit,
Carboniferous limestone,
Old Red Sandstone,
Lower Silurian,
Metamorphic rocks, probably Cambrian.

Associated with these are hornblend-rock, greenstone, felspathic trap, elvan dykes, and granite.

The country is low, and in general gently undulating, the loftiest point being Holyhead mountain, 709 feet above the sea; the next Garn near Llanfairynghornwy, 558 feet; and the greatest elevation crossed by the sections, in Sheet No. 40, is only about 420 feet high. The surface is in a great measure composed of drift, boulders, earthy gravel, sand, and clay, through which

the rocks of the country frequently appear in barren tracks or small broken bosses, covered with heath or furze. When freshly stripped of soil or drift, these rocks are often found to be smoothed and marked with striæ, running generally from 20° to 40° west of south.

This arrangement is connected with the direction of the main valleys of the country, which run from north-east to south-west, the chief of these being occupied by Malldraeth Marsh. The Menai Straits themselves run in a similar hollow at a lower level.

Though the chief object of this memoir is only to describe the Cambrian and Silurian rocks, yet all the above-named formations lie so compactly in the island that it is as well in this place to give a general description of the whole.

The Cambrian and Silurian rocks of Anglesey in great part resemble those in Caernarvonshire, described in last chapter. The Silurian strata of the island are often rich in Caradoc or Bala and Llandeilo fossils, and the Cambrian rocks as a rule are highly metamorphic, like those between Bardsey Island and Nevin in the promontory of Lleyn. Both Cambrian and Silurian strata are in places associated with granite, and the Silurian rocks themselves occasionally assume the form of Mica schist and Gneiss. Under these circumstances it is not always certain that some of the Silurian may not have been included inadvertently among the so-called Cambrian strata; for by far the larger part of the metamorphic rocks of Anglesey apparently belonging to the latter formation, and in mapping the country it was natural in doubtful cases rather to class the metamorphosed rocks with Cambrian than with Silurian beds.

The grounds on which the larger part of Anglesey is considered to consist of Cambrian rocks, will be best understood by comparing the following description with the 1-inch maps, Nos. 77 and 78.

It has has been shown that where the Cambrian rocks approach the Llyn Padarn porphyry they are much altered, especially to the south-west near Glynllyfon. Close to the Menai Straits, near Bangor, rocks of the same character, under like circumstances, are also changed, and if we prolong their strike and that of the overlying Silurian beds, from Bangor under the Lavan sands to Beaumaris, and from thence to Glan-y-ffynnon at the east point of Red Wharf Bay, we find an association similar to that of Bangor, black shales resting on green, grey, and purple schists and grits, which, however much foliated and contorted, still bear as strong a resemblance to the Cambrian rocks of Bangor as the latter do to those of Llanberis and the Ogwen, thus by insensible gradations uniting the whole.

The same black Silurian shales interruptedly skirt the coast of Red Wharf Bay to Tyddyn-y-waun, and along this range the metamorphic schist and the quartz rock of Mynydd Llwydiarth dip distinctly under them. South-west, between Red Wharf Bay and Malldraeth Marsh, wherever the rocks are unfaulted the same order prevails; and it is thus probable that the broad band of

foliated rocks that lies between the Menai Straits and Malldraeth Marsh, form a faulted anticlinal curve of Cambrian rocks thoroughly metamorphosed, on either side of which the Silurian strata are thrown off, on the south-east between Bangor and Caernarvon, and on the north-west between Red Wharf Bay and Malldraeth Marsh.

Restoring the curvatures of the Cambrian and Silurian strata, and disregarding minor effects produced by faults, we find similar metamorphic rocks north-west of Malldraeth Marsh, foliated and contorted, and bounded somewhat obscurely by faulted Silurian rocks, which, beyond the granite, rise to the north-west. From under them in that direction green, grey, and purple metamorphic schists and quartz-rock and foliated beds again come to the surface, forming the north-west coast of Anglesey and the island of Holyhead. The Silurian strata occupy a broad space in the middle of the north part of the island, certainly overlying the presumed Cambrian rocks on the west, but bounded on the north by a remarkable curved fault, which throws them down against a series of hard thick-bedded greenish grits, purple and grey schists, and foliated rocks, many of the less metamorphosed beds of which at once remind the geologist of the Cambrian grits of Caernarvonshire. There are, however, Silurian beds on the north coast, at Cemmaes, consisting of black shales, grits, and limestones, partly metamorphosed, and mixed with metamorphic rocks; and though I have little doubt of the Cambrian date of the rocks south of Llanfechell, it must be confessed that, even where coloured Cambrian, doubts exist respecting the Silurian or Cambrian date of some of the rocks near and on parts of the north coast.

In the north half of Anglesey the Silurian rocks that cross the island from Dulas Bay towards Cymmeran Bay consist of black shales and grey grits, the latter generally lying near the base, and containing Caradoc or Bala fossils. This is important, for no Lingula flags have yet been detected in the country, and it is probable that they have been unconformably overlapped before reaching this northern area, for they are reduced from 6,000 to 2,000 feet between Merionethshire and Llanberis, have still further dwindled on the south-west towards Clynnog-fawr, and seem to have almost or altogether thinned away before reaching Bangor and Anglesey.

The Old Red Sandstone of Anglesey lies unconformably alike on Silurian and Cambrian strata, and strikes in a long narrow strip from Dulas Bay, on the east coast, to Llangefni, where it is overlapped by the Carboniferous limestone, which occupying a broad tract on the coast south of Lligwy Bay, strikes south-west and underlies the coal-field of Malldraeth Marsh. The Old Red Sandstone of Anglesey belongs indeed to those upper strata of that formation common in Ireland, which some geologists consider as being more intimately related to the Carboniferous rocks than with the so-called middle or lower divisions of the Old Red series. The Carboniferous limestone in detached masses also occupies part of the coast of the Menai Straits, and the angle of the

island beyond Beaumaris, between Red Wharf Bay and the Outer Road.

The Millstone grit appears above it on the slopes skirting Malldraeth Marsh, and the overlying coal-measures rarely show themselves in natural sections from beneath the covering of peat, gravel, sand, and sheets of water that form the marsh.

The Permian strata nowhere actually show at the surface, but I inferred their existence from the lithological character of the red marls, sandstones, and conglomerates at the mouths of the coal pits, and from ascertaining that undoubtedly the coal-measure sandstones, shales, and beds of coal crop upwards against the base of the red rocks which rest quite unconformably upon them. Coal-measures and Permian strata have both been preserved simply by the accident of the north-east fault that bounds the marsh having thrown them down so low, that a fragment of strata that once, I have no doubt, spread over the entire island has been saved from entire denudation. Such is a general sketch of the stratigraphical relations of the rocks of Anglesey. The remainder is matter of detail.

Cambrian rocks.—The Cambrian strata of Anglesey being wholly metamorphic, and the Silurian rocks being metamorphosed in part, there is reason to believe that their metamorphism was contemporaneous and of Lower Silurian date, being connected with the presence of granite, probably of the same age with the imperfectly granitic rock and quartz porphyry on the opposite side of the straits. The south-west part of the island is formed of a belt of metamorphic rocks from 2 to 4 miles wide, that strikes north-east from Newborough sands across the island to Beaumaris and Llanddona. They are as thoroughly metamorphosed as almost any part of the rocks in Anglesey. In the southern part of this area I have described them as "green, grey, and purple, siliceous, chloritic, and micaceous schistose rocks, "intensely foliated in numerous small contortions,"* or, in other words, of siliceous mica schists, tinged with chlorite, or of thin layers of quartz alternating with grey and green micaceous and chloritic laminæ, the whole intensely contorted in wavy and twisted layers like many other gneissic rocks. Near Llanfihangel Esgeifiog, north of the Holyhead road, by the marsh, the rock is thoroughly metamorphosed into gneiss, consisting of quartzose and felspathic foliations intermingled with bands of hornblende and mica. The details of their structure constantly vary, and yet the whole remains so much the same that minute descriptions of individual spots would convey little information. Foliation is often intimately connected with stratification. In certain unmetamorphosed rocks, probably under much pressure, at great depths, and influenced by long-continued heat, moisture, &c., the substances that formed the original strata became more or less decomposed, and re-arranged themselves according to the chemical affinities of their constituents. This is one species of metamorphism, and it will thus be easily understood how it will be easy to find pieces of clay, shale, slate, mica schist, and gneiss, not differing more on analysis than two pieces of gneiss do from each other. There seems, however, under such circumstances, generally to be a tendency in the reconstituted substances to re-arrange themselves more or less in the direction of pre-existing planes. Judging by the relation of these rocks to the rest of North Wales, it is possible that to a great extent the metamorphism of the rocks took place before the production of those larger contortions of the strata that induced cleavage, and in that case it is probable that, though the traces of original bedding are obscured, the foliation lines often still approximately indicate the original direction of the layers of bedding, and the greater curves marked by the average direction of the foliated laminæ are nearly equivalent to ordinary curvatures

* Six-inch Horizontal Section, sheet 40, line 3.

of the strata. Notwithstanding minor contortions, they seem, on the whole, in this part of the island, to dip north-west and south-east, the central axis, as shown in the 6-inch section, (sheet 40), lying somewhat nearer the Carboniferous limestone of the straits than the coal-field of Malldraeth Marsh. Further north-east in the same general strike, it is again worthy of remark that, exclusive of minor contortions, the foliated strata in this section lie in the form of an anticlinal curve, the axis of which is about half a mile north-west of Menai Bridge. From this point the foliated metamorphic strata dip south-east under the straits, and the higher Cambrian rocks on the Caernarvonshire side, dipping in the same direction at high angles, are immediately overlaid by Lower Silurian strata. On the Anglesey side of the curve the Silurian beds (faulted however) are thrown in by Plas Gwyn near Pentraeth, in that long strip which runs from thence to Plas Berw on the east side of the Coal-measures, thus completing the series, and adding to the proofs of the Cambrian age of most of the metamorphic rocks of Anglesey.*

Crossing the Carboniferous rocks of Malldraeth Marsh the geologist at once recognizes the seeming equivalents of the metamorphic Cambrian strata nearer the straits, consisting partly of "grey and purple, but chiefly green schistose "rocks, often chloritic, micaceous, and siliceous, with occasional patches of "granular limestone and nests of jasper; the whole intensely foliated in "numerous small contortions."† The foliations probably indicate approximately the direction of the original lines of bedding, and if so the whole forms a basin, the layers undulating north-west between the Carboniferous limestone and the higher part of the river Cefni, and south-east from the river to what is believed to be a north-east fault that strikes through Tregaian. It may here be stated that the evidence of this fault consists simply of this, that along a straight line certain Silurian shaly beds dip towards and apparently *under* the metamorphic strata, which there is no good ground for separating from the Cambrian rocks on the other side of the coal-field; but at the same time it is impossible to deny that it is *possible* the gneissic schists by the Cefni may be metamorphosed Silurian resting on an unaltered part of the same formation, and the same may be said of the strip of rock that skirts the granite on the south-west towards the sea.

Beyond the granite, in the western part of the island, the boundary between the true Silurian and the presumed Cambrian rocks is only approximate, being obscured by drift. On the north-east near Pen-y-groes (between Llanfaethlu and Llanflewin) the broken rocks, full of quartz veins close to the junction, may indicate a fault; and if there be true Cambrian rocks in this district, and if the foliation indicates the general dip of the rocks, there may also be a fault at Presaddfedd (east of Bodedern), for the undoubted Silurian beds dip south-east, and the older rocks north-west. The whole boundary is, however, uncertain, and though I believe the mass that skirts the coast is probably Cambrian, it is possible that part or even the whole of it may only be metamorphic Silurian. The nature of these rocks is best seen on the coasts of Anglesey and Holyhead Island.

In Anglesey, north of the Holyhead road, the rocks consist of green and purple schist, often micaceous, lying in wavy laminæ undulating north and south at angles rarely over 20°. The colours of the rocks are more like those of the Cambrian than of the Silurian rocks of Caernarvonshire. At Porth-y-defaid, below Trefadog, there are green laminated schists with steatite, inclined south-east at 40°. North of Church Bay, towards Porth-y-dwr, the rock is principally a white or yellow felspathic schist, weathering brown, often wavy and serpentinous. In Church Bay part of these beds is soft and decomposing, and is associated with beds of quartz-rock and conglomerate. Between Church Bay and Carmels Point, at the north-west corner of Anglesey, I cannot better describe the rocks than by referring to my description of Section No. 2, sheet 40:—

"This section, from Carmels Point to the north shore of Church Bay, is little more than 2 miles in length, running from north to south across one of the most faulted and metamorphic parts of Anglesey. Some of the faults are

* See Maps 77 and 78, and Sections lines 1 and 3, sheet 40.

† See description of Section, sheet 40, by myself.

seen on the neighbouring sea-cliffs, and others are inferred by closely approximating strata striking towards each other in a manner impossible without faults.

"On the north by the shore a few poor fossils, in irregular bands of limestone, indicate the Caradoc or Bala age of the beds. The limestone is impure, inconstant, and of no economic value. Black wavy shales succeed these, faulted against gneissic rocks. The fault is a lode containing brown iron ore and coppper pyrites. Through the foliated rocks, that seem to be altered Silurian, on Penbryn-yr-Eglwys, granite veins ramify in all directions, some of which may be distinctly seen on the neighbouring sea-cliff. Further south, in a broken country, narrow strips of black Silurian shale are faulted in between patches of metamorphic rocks foliated in wavy lines of quartz, interlaminated with green and purple gritty and schistose layers. On the south, towards Church Bay, the metamorphism is so extreme that in places the bedding has entirely disappeared, and without careful inspection and a knowledge of the whole neighbouring country, the rocks might be mistaken for igneous masses. There is no perfect security that the patches marked Cambrian in this section and their continuation southward to Holyhead Island are not some part of the Lower Silurian strata metamorphosed, and the chief reason why they are believed to be Cambrian is that they underlie all the undoubted Silurian beds, and besides seem to bear a strong general resemblance to the metamorphic strata that lie on the north-west shores of the Menai Straits, which, as already stated, are the completely metamorphosed continuation of the less altered rocks of Bangor."

Among other points, it will be noticed that in this part of Anglesey the bedding and foliation cross each other. The bedding, though often very obscure, is nevertheless sufficiently plain to the practised eye to indicate this fact. The more definite lines pass in places into a species of waving imperfect foliation that may have originally been cleavage, and the phenomena of this kind generally may be due to the circumstance that part of the country was contorted, compressed, and cleaved before the general metamorphism of Anglesey began; or, what is unlikely, that the metamorphism of the rocks of this corner is of later date than that of the country generally; or else that cleavage and foliation were in this and other cases simultaneous. It may be, also, that the foliation partly lies in original lines of false-bedding.

In this corner of the island these phenomena are common both to the undoubted Silurian shales and to the presumed Cambrian schists, which it is here impossible satisfactorily to separate, the Silurian rocks themselves being in places metamorphic. In Church Bay, where the metamorphism is extreme, the joints are exceedingly numerous, and cross each other in all directions. The rock is extremely hard and homogeneous, the bedding obscure, and the foliation itself, which undulates north-westerly at angles of about 40°, is often indistinct. A little way in the interior, however, the wavy lines are sufficiently distinct, and the metamorphic nature of the rock becomes evident.

Holyhead Island.—Metamorphism.

Holyhead Island properly forms a portion of the Cambrian rocks of the west of Anglesey. Near its southern end, on both sides of the strait that divides the islands, there are several large masses of serpentine, one skirting Llyn treflas, others bordering the sands of Tywyntrewan, another by the shore near Four Mile Bridge, and the largest of all on Holyhead Island itself. The rock is of a mottled blueish-green colour, and capable of an excellent polish. It here and there contain a little asbestos. Each boss as a whole lies in wavy contorted lines like the other foliated rocks of the country, dipping in the same direction, and conveying the impression, which is undoubtedly true, that they are metamorphic masses. This belief gains force from the circumstance that in undoubted schists near Amlwch, far from large masses of serpentine, there are many thin wavy laminar lines of serpentine forming part of the ordinary metamorphic strata.

A fault traverses Holyhead Island from Borth-wen on the south-east to Gogarth on the north-west. The evidence consists in conflicting dips both in the interior and on the coast cliffs of Gogarth, Porth-y-corwgl, Bwa-du, and Borth-wen, where the break is plain. It is probably a downthrow on the east. On its eastern side, the strata, though foliated and contorted, are in general

much less disturbed than on the west, where the contortions are often extreme. The lower strata in fact have suffered the greatest change.

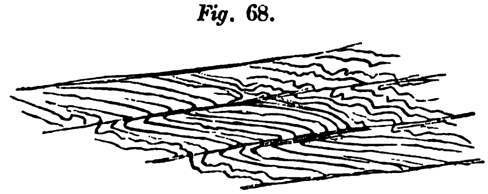
Between Borth-wen and Bwa-du (near Rhoscolyn), the rocks chiefly consist of grits, including thick beds of quartz rock, occasionally inter-stratified with greenish grey quartzose schist, and at Borth-saint there is a bed of "China stone," or very felspathic grit much decomposed. Stratification, foliation, and cleavage are, perhaps, all and each often sufficiently distinct, but again they are sometimes inseparable, or, in other words, it is difficult to say if foliation and bedding coincide, or foliation and cleavage, or if the foliation has nothing to do with either. On a rock by the coast opposite Maen-y-fran there is the following appearance, the lines inclined in the direction of the arrow being

Fig. 67.

bedding, and the twisted lines foliated interlaminations of quartz and quartzose schist, which, it will be observed, except in one place, are always suddenly bent at the junction of the beds. This is common in Anglesey, and is not a mere change of angle, like that which often takes place in slaty cleavage when it passes from a fine to a coarse stratum. I am, however, inclined to think there is an unexplained connexion between them, and that the nearly straight lines suddenly and sharply bent at the junction of the beds and curving in others, may represent a species of cleavage and foliation in one, viz., that the pressure that under ordinary circumstances would have produced simple cleavage, has here, under the contemporaneous influence of metamorphic action, resulted in a complex foliation of the cleavage planes. At Bwagwyn there are similar appearances, the strata dipping E. 30° N. at 30°, and the foliated-looking cleavage N. 25° W. from 50° to 60°.

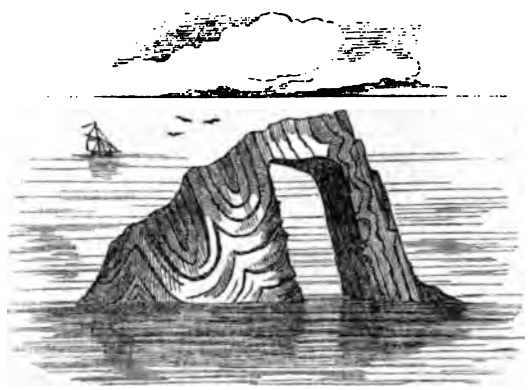
Between Bwa-du and Porth-y-corwgl, for several miles along the coast, the rocks lie on the east side of the fault, which here probably strikes across the bay. They consist of greenish-grey sandy micaceous schists, curving in low undulations, the layers rarely rising to angles of 30°, and between the mis-named Cromlech and Porth-y-post, they lie in waving lines at angles still lower. All of these rocks are, however, intensely foliated, often in small and sharp contortions, the angles of which, though acute, are so arranged that the entire lines lie at low angles, and may, as a whole, be said to be almost horizontal.

Fig. 68.



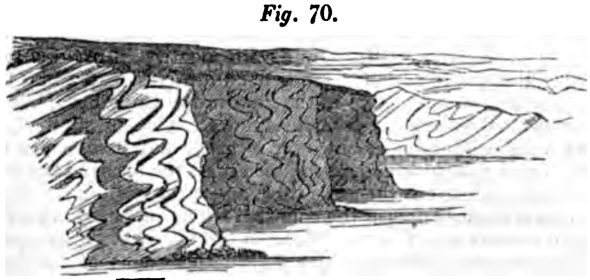
From Porth-y-corwgl to the South Stack and Gogarth, the rocks along the coast in a great degree consist of grits, mingled with occasional greenish-grey foliated micaceous schists. These grits, partly resisting denudation from their superior hardness, often stand out from the cliffs as little islets, characteristic of the west coast of Holyhead Island. Both islet and coast cliffs present,

Fig. 69.



perhaps, the finest cases in Wales of violently contorted strata. Sometimes the gnarled lines lie in rapid folds, running zigzag up the cliff, striking examples of which occur on the southern coast of Penrhos-fllo.

Fig. 70.

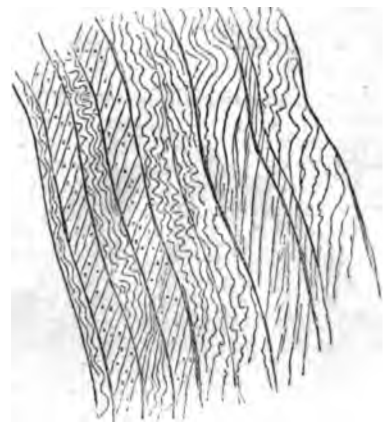


In others the strata as a whole run vertically from the bottom to the top of the cliffs, being at the same time bent backwards and forwards into a number of horizontal folds. Again, as for instance opposite the South Stack, the contortions, though still intense, have a more gently flowing outline.

As a whole, for about three miles south-east of the South Stack the highly inclined and waving beds *seem* to dip steadily north-westerly, at angles from 60° to 80°; yet so intense is the contortion that even then it is never certain that the outcropping edges of the beds may not be mere fragments of large curves, the sharply doubled up strata showing no sign of the curvature, for the tops of the bends have been cut off by denudation, while their bases lie below the sea. If the metamorphism of these and the Anglesey rocks be of Lower Silurian date, then they must have been subjected to two forces incident to that epoch, one from below and local, during the process of metamorphic action, and another of more general application, when all the Lower Silurian rocks of Wales were upheaved and thrown into broad undulations before the deposition of the Upper Silurian strata. These forces acting on rocks then buried deeply beneath great masses since removed by denudation, have produced in places a vertical folding of the layers, as in Fig. 70, like many folds of paper crumpled in the hand.

Opposite the South Stack the contorted rocks in the upper part of the cliff consist of very hard quartzose grits, while below they are intermingled with schistose bands. Here the foliation of the rocks is worth special attention. In one of the curves, where the strata for a space dip south-easterly at a high angle, I observed first, that the distinct beds consist of sandy and schistose alternations, and second, that they seemed partly foliated and partly in lines without clear foliation. In the following diagram the sandy beds, No. 1, are marked with dots and in these I saw no separation of distinct layers of

Fig. 71.



2 1 3 1 4 5

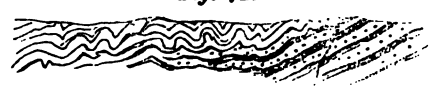
different mineral substances, such as would be called foliation in the sense in which it is used by Mr. Darwin, but only a sort of imperfect separation of material sometimes arranged in slightly wavy lines; while in the schistose beds complete foliation appears, with much twisting of quartzose and micaceous laminæ, each bed, however, still retaining its identity. In No. 2 these contorted laminæ follow the direction of the bed, and in Nos. 3, 4, and 5 they cross the beds, somewhat in the direction of the lines in the sandy beds, but (eliminating the contortions) at slightly different angles. The question is, Do these lines that cross the bedding represent both *cleavage* and *foliation*, or may they not rather represent *false bedding* and *foliation*? If the former, then were cleavage and foliation produced at the same time, and what relation do they bear to the larger physical disturbances of the country? The supposed imperfect cleavage in the gritty bands would be, according to the theory of Sorby and Tyndal, the result of mechanical pressure, which forced the grains of the beds to re-arrange themselves in certain planes. In such beds, the whole being quartzose, there were no ingredients present to separate into differ laminæ, under the influence of metamorphic action; whereas in the schistose strata, originally, like other muddy shales, consisting chiefly of clay and finely-divided particles of silica, we have all the materials present, by a re-arrangement of which, according to their chemical affinities, metamorphic foliation might be produced. On the hypothesis now discussed, this metamorphism must have taken place either before or at the time that cleavage was being formed, both in the grits and associated shales, or if not, then metamorphism was effected at a later date where cleavage planes pre-existed. If the metamorphism was of Lower Silurian date, then it is not likely that the cleavage pre-existed that metamorphism, for it is almost certain that the cleavage of the Lower Silurian rocks of North Wales was a consequence of those contortions of the strata that preceded the deposition of the Upper Llandovery rocks. But if cleavage and metamorphism were contemporaneous, then the average difference of angle in the lines of foliation in the grits and schists may perhaps be comparable to that so common in ordinary *slaty* countries when cleavage planes pass from true slaty bands into beds of grit. If, however, cleavage preceded the metamorphism, then the foliated laminæ represent cleavage planes on which foliation with contortion of the foliated laminæ supervened. One other explanation remains, which is perhaps the most probable, viz., that the foliated lines in the schist, and the unfoliated cross lines in the gritty beds, may lie in original lines of false bedding, an observation also made by Mr. Sorby, for as it is certain that on a great scale foliation often coincides with stratification, so on a small scale it must often coincide with the minor planes of false bedding, the re-arrangement of material taking place in pre-existing lines.

East of the South Stack the rocks consist of "China stone," a felspathic grit, with contorted foliation dipping south at angles between 60° and 80°, and

some of the beds become a kind of quartz-rock. But by far the largest body of this latter substance in the island forms the eastern half of Holyhead Mountain. This mass extends along the north shore from the lofty cliffs of Gogarth to the point of Penrhyn-garw. On the west it is bounded by a fault, and on the south-east it dips at low angles and undulates beneath the beds of foliated micaceous schist that form the remainder of the island.

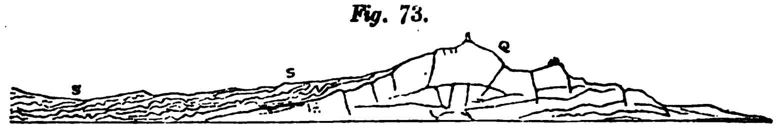
But though a careful examination of the boundary leads a skilled observer to the conclusion that the quartz rock dips easterly under the schist, on the mountain itself the bedding is either obscure or utterly obliterated. In the great quarries from which the quartz rock for the breakwater was obtained, no bedding is visible, while innumerable joints traverse the rock in all directions, some of them close and small, others large and far apart, so that when blasted the rock is sometimes shivered into fragments and sometimes falls in great masses. The greater joints run approximately north and south and east and west, and it was by taking advantage of them in the construction of their galleries that as much as 118,000 tons of rock have been brought down at a single blasting. Nevertheless, though invisible in the quarry, on the sea cliffs, where well-weathered sections are exposed, the bedding often becomes distinct, and at the junction near Penrhyn-garw beds of quartz rock may be seen dipping easterly under contorted foliated schist on a low cliff on the shore.

Fig. 72.



A section across the mountain from north-west to south-east gives the following arrangement of strata:—

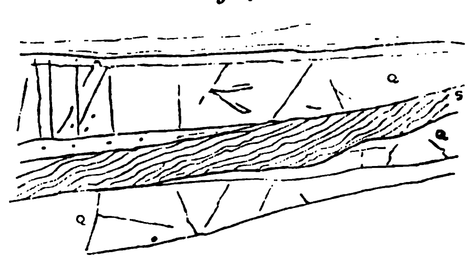
Fig. 73.



Q. Quartz rock.
S. Contorted foliated micaceous schist with numerous quartz laminæ.

Viewed as a whole, the bedding and foliation seem to dip in the same general direction, as shown in diagram No. 72, but the little foliated contortions are intense and rapid in the schist, while a careful study of the whole mountain makes it plain that the quartz rock lies in larger curves. Sometimes, however, as on the other side of the island, there seems only this connection between them, that they dip on the whole in the same direction, the dip of the foliation in the schistose or gneissic beds being, however, somewhat greater than in the beds of quartz rock. Thus at Porth-narmach, near the north end of the greenstone dyke, I observed the following appearance:—

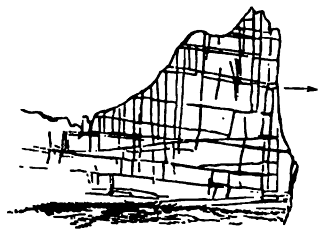
Fig. 74.



Q. Quartz rock. S. Foliated micaceous schist.

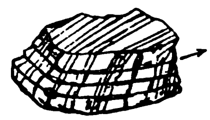
The larger strata are here lenticular and false bedded, and it may be that the oblique foliations in the schist lie in the minor planes of a cross stratification. But there are other examples between this and the North Stack, where it is different. In one instance the undulating micaceous quartzose strata dip

Fig. 75.



slightly north-west with a little false bedding; and a vertical lamination that seems distinct from jointing, but is possibly allied to cleavage, passes across these lines. In another case, where the strata also lie nearly horizontally, I observed lines not so close as those of good cleavage, which, nearly at right angles to the bedding separated the rock into laminæ of different colours like an imperfect foliation, and at the same time passed right through the middle of some of the pebbles which it enclosed, as in Fig. 73. This, but for the different

Fig. 76.

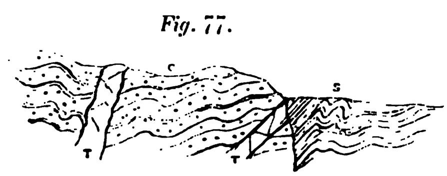


coloured laminæ, would look like jointing, but at present I am unable to explain some of these phenomena, though I do not doubt that a long-continued and enlarged study of them over the islands of Holyhead and Anglesey might lead to important results.

Dykes.—Several greenstone dykes traverse the island in a north-west direction. One of these almost continuously crosses the general strike of the strata for about 7 miles from Cymmeran Bay to Porth-namarch. Four others lie between it and the west coast, running in the same general direction, which is also that of the fault which crosses Holyhead Mountain between Gogarth and Porth-y-corwgl, and all coincide more or less with the run of many of the larger joints. A short dyke lies to the north of the town of Holyhead.

The North of Anglesey.—From east to west between Carmels Point and Point Ælianus, nearly the whole of the north of Anglesey is coloured Cambrian. The inland part of this area is bounded on the south by faults, easily inferred by the discordant dips and strikes, both in the interior and on the coast cliffs, between the ordinary and black Silurian shales and the foliated schist and contorted grits of the north. This inference is further confirmed by the circumstance that a number of greenstone and felspathic trap or elvan dykes, south of Llanfechell suddenly cease at the presumed line of dislocation, which we should scarcely expect if the Silurian beds dipped under the foliated grits of Llyn-Felin-y-nant instead of being faulted against them. Grits and dykes are therefore suddenly cut off by a downthrow of black shales on the south. The geological date of these dykes is uncertain, but probably, like those of Holyhead, they are comparatively old; for it seems likely that they were intruded into mere fissures and joints which are not faults, before the great fractures took place that threw the Silurian strata against what seems to be a low part of the Cambrian grits, and that for the following reasons:—

Fig. 77.



S. Silurian shales.
C. Cambrian rocks.
T. Dykes.

The Silurian rocks S once covered the Cambrian grits C, which are pierced by the dykes T, in which case it would appear probable that the melted matter was merely injected into deep-seated cracks, and did not reach the level of the overlying Silurian shales; for, if they ever pierced these overlying shales, it is improbable that each dyke should stop suddenly short at what is now the line of fault that cuts them off, seeing that the balance of chances must surely be much against all of these dykes originally suddenly ceasing in a line now coincident with the dislocation, not one of them having being prolonged beyond this line into the continuation of those once unfaulted grits that must now lie deep below the Silurian strata.

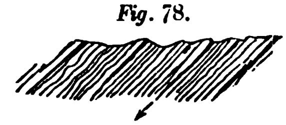
The above-mentioned grits are the lowest Cambrian beds in this part of the island, and, though altered or foliated, yet lithologically they still bear much resemblance to the purple and green grits and slaty bands that form the Cambrian beds in Merionethshire. They occupy a large section of the country between Llanfairynghornwy, Llanflewin, and Bodewryd, and may be described as green altered grits interstratified with greenish grey and purple slaty shales, containing layers and sometimes beds of serpentine, examples of which occur between Llanfechell and Llanfairynghornwy, near chapel, another near Cefn-coch, and another in overlying strata at Tre'r-gela near Cemmaes Bay.

The veined structure of the serpentines here also accords with the foliation, and the grits themselves are foliated in numerous small contortions of quartz alternating with a more sedimentary-looking material. The metamorphism increases in intensity in the lower beds towards the fault, where the elvan dykes are most numerous; but as the dykes seem only to alter the metamorphic strata slightly in the manner of ordinary dykes, I do not believe that their presence is in any way connected with the metamorphism. The dykes, as already remarked, are altogether of later date, and from their direction may be of the same age with the greenstone dykes that traverse the Cambrian rocks of Llanberis and Nant Francon, one of which in the Penrhyn slate quarries contained a fragment of cleaved slate. They are probably post-carboniferous.

With many minor curves, the northern dip of the strata is unusually clear in the broken low rocky hills, often almost bare of vegetation, that surround the lakes and pools of Mynydd Mechell, and though obscure in the softer shaly ground beyond, there is reason to believe that there is a general ascending section all the way from the fault near Llanflewin to the north coast by Cemmaes Bay and Llanbadrig, where some of the higher strata are clearly Lower Silurian, but other parts are of doubtful age, though apparently underlying these Silurian strata. On the north shore, between Yr-hên borth and Cemmaes Bay, the rocks consist of blueish-grey, green, and purple schists interstratified with each other, sometimes foliated with quartz laminæ arranged in wavy lines, which undulate at low angles to the north-east; and agreeing as they do with the true north-east dip of the grits above described, these wavy lines apparently coincide with the actual bedding of the strata. Striking to the south-east a part of them appear in the green and purple slaty shales that form the low soft country beween Rhosbeirio and Cemmaes. The rocks still further eastward, by Amlwch, are perhaps the general equivalents of the same strata, but as a whole they are much more metamorphosed. Their lithological character is generally similar to that which marks all the Cambrian rocks of Anglesey, consisting of "greenish grey, green, and sometimes purple meta-" morphic slaty beds, with imperfect cleavage, and frequently intensely con-" torted foliation." This foliation consists of numerous quartz laminæ, strongly contorted with layers of green and purple schistose matter, sometimes interlaminated with very thin layers of serpentine, proving in this neighbourhood the metamorphic origin of that mineral, even more than the patches on a larger scale neâr Llanfechell and Holyhead Island, in which, as already stated, the wavy lines are so closely allied to those of foliation.

But in the Amlwch district this intense foliation only rarely coincides with the lines of bedding. Thus, near Point Ælianus, about 100 yards south of the lighthouse, I observed one case in which bedding and foliated lines seemed to agree, thus—

Fig. 78.



Between the lighthouse and the point there is a divergence in the lines which

Fig. 79.

at the point itself is increased, the strata dipping 35° N. 26° W., and the bedding is crossed at angles of about 63° to the horizon by lines, in one place slightly twisted, as in Fig. 81.

Fig. 80.

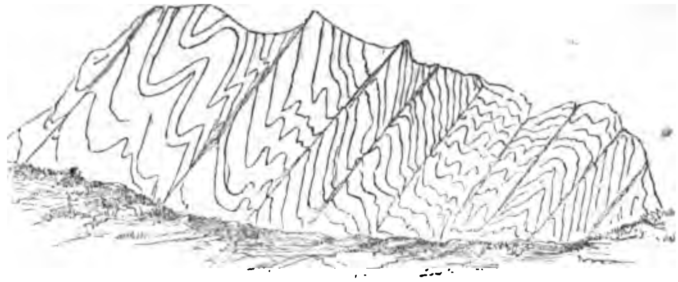
Near Bod Ednyfed-bach, about three-quarters of a mile south-east of Amlwch, in one of the bare rocky bosses that project through the soil, I observed the appearance presented by the following diagram:—

Fig. 81.

in which the straight inclined lines dipping at angles of 71° represent bedding, and the waving lines foliation, the quartz laminæ of which vary from a mere line to a quarter of an inch in thickness. It will be observed that these lines have a tendency to form an acute angle with the bedding, but are suddenly bent in a double curve just at the point where they pass from one stratum to another.

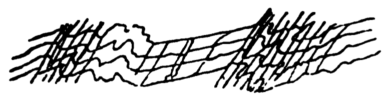
Between Amlwch and Llaneilian the following little section is exposed:—

Fig. 82.



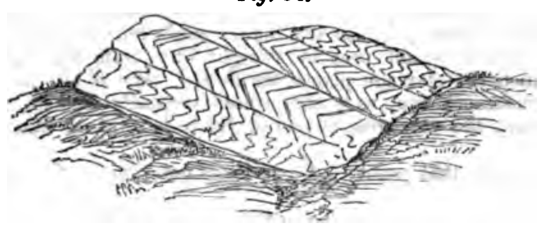
in which the foliation also has a partial tendency to form an acute angle with and dip somewhat in the direction of the lines of bedding; while in another instance, near the lighthouse, intensely contorted and wavy foliated lines cross each other at much higher angles—

Fig. 83.



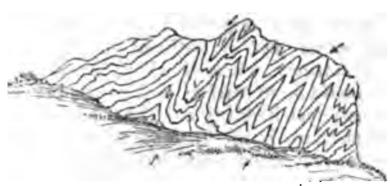
the contorted lines in which much resemble foliation, and in this case probably indicate stratification. In the same neighbourhood, nearer the fault, in one instance where what I took for bedding dips at a high angle, the foliated lines highly contorted run, on an average, right across the dip, while again in the neighbourhood of No. 78 the foliations run zigzag right across the bedding, in the manner shown in the following diagram:—

Fig. 84.



In innumerable other cases the bedding is indeterminable, and nothing but the intensest foliation remains, although, from frequent experience, even

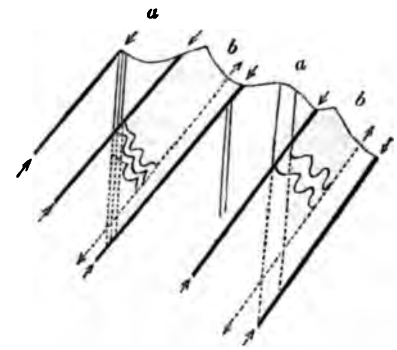
Fig. 85.



then the observer is apt to consider that the bends and twist are connected with, and perhaps indicate, obliterated lines of beddings which if present would run in the direction of the arrows on opposite sides of the woodcut.

On the whole I believe that, as there is necessarily a relation between cleavage and bedding in strike and dip, so there is often a connexion in strike and dip between bedding and foliation, for though the latter in Anglesey generally crosses the former at some angle, the stratification as a whole dips northerly, and the foliations with innumerable twists seem in the main inclined in the same direction. In the cases cited also, it is exceptional to find what I have termed nearly straight foliated cleavage, but in the contorted examples illustrated by diagrams Nos. 80 to 85 there may still be a connexion between bedding cleavage and foliation, and the following explanation of the phenomena seems to me in many cases not unreasonable. Suppose true slaty cleavage to cut in straight lines through beds inclined at any angle, and that afterwards foliation was superinduced in the line of the cleavage planes; then, while foliation was being produced by a chemical re-arrangement of matter accompanied by moisture and heat, the expansion produced by heat at great depths would induce intense pressure, one result of which might be, that such pressure, if exerted vertically from below, would in some instances compress the beds and reduce their individual thickness without obliterating the stratification, while *the foliated cleavage planes also vertically compressed might be forced into contorted lines more or less across the planes of bedding,* thus—

Fig. 86.



Let the strong lines with arrows pointing at each other represent true beds, and let the fainter lines inclined at a higher angle represent cleavage, which in its ordinary state would pass in straight lines from the beds *a* to the beds *b*, in which the cleavage planes are dotted, then if all the beds, while undergoing metamorphism, were compressed vertically by heat and expansion from below, the very compression of the beds *b* into a minor thickness, say from the arrows that point ↗↙ to those pointing ↙↗, would contort the foliated cleavage planes by forcing them to occupy smaller spaces proportionate to the diminished thickness of the beds; so that the straight dotted lines would become curved in the manner shown in the diagram.

When I speak of pressure from below by expansion, I consider it to be self-evident that the present surface then lay deep underneath, the heavy pile of strata under which it lay having since been removed by denudation, and it was the weight of this great pile, opposed to the expansive pressure below, *that when the strata lay either flat or inclined compressed them into thinner beds and contorted the foliations,* whereas when strata stood vertically the *tendency of the pressure would be to thicken or increase the width of the bed* if indeed under such circumstances bedding could be detected at all.

It may thus happen that there is an intimate relationship between bedding, cleavage, and foliation; for it is known and has long been accounted for that on a large scale the dip of slaty cleavage is now and then coincident with the bedding. In general cleavage and bedding are inclined in the same *average* direction on the opposite sides of the greater curves of disturbed strata, the explanation being that the pressure that produced the curvatures also produced the cleavage in parts of the formations that lay deep underground. Therefore it happens that if contorted foliation supervene, the wavy lines will also show a relation to the dips of the original lines of bedding.

There are other cases, however, in which I believe, with Mr. Sorby, that the planes of foliation coincide with true or with false bedding, perhaps only an imperfect cleavage, or none at all, having been present when metamorphism took place. In the case of foliated false bedding, the foliations might still be contorted, while the massive beds at certain angles of inclination would be compressed.

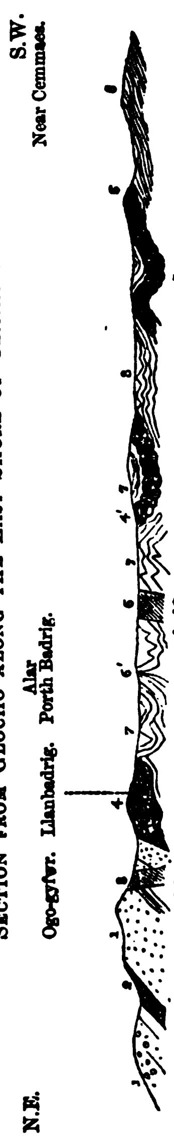
Cemmaes limestones, &c.—I shall now briefly describe the most northern part of the island, where the limestones and other rocks of Cemmaes Bay appear to be the highest beds of this series. The greater part of these are much contorted, highly metamorphosed, and greatly broken by faults. In Porth Badric and at Ogo-gyfwr, in the midst of these faults, there are two streaks of ordinary black Silurian shale, the most southern of which contains graptolites, but all the remainder of the strata seem to be unfossiliferous, and consist of bands of limestone, sometimes impure and siliceous, and banded with inconstant black shaly layers. The limestone is often highly crystalline, and has been broken by intense pressure into numerous fragments, and re-cemented by calcareous veins. These bands are interstratified with beds of grey and blue altered gritty shales (sometimes nodular), and with quartz-rock, the whole being so excessively con-

torted and broken that "smashed" is the only word by which their appearance can be expressed. In Porth Badric itself there are great beds known as China stone, a kind of felspathic quartz-rock, which is traversed by many ferruginous veins, and in which the bedding is indistinct. These masses have been quarried and ground to mix with China clay, and the substance is also said to have been used for the adulteration of guano.

Beyond the limestones on the cliffs of Glocho and Hell's Mouth there are beds of quartz-conglomerate and quartz-rock (in which there are "China-stone" quarries) dipping northerly at angles from 50° to 60°. The arrangement of the whole, faulted and contorted, about three-quarters of a mile east of Porth Badrig, is shown in the six-inch section, Sheet No. 40. The section close to the shore is rather more complete, and the rocks lie nearly as shown in the following diagram:—

No. 1 represents quartz-conglomerate and quartz-rock enclosing a band of limestone No. 2, immediately north of Ogo-gyfwr, where a band of black shale, No. 3, with gritty bands, is let in between two faults; No. 4 is the band of broken limestone on which Llan-Badrig stands, which is repeated by a faulted anticlinal curve at No. 4′ where it again rises, overlaid by broken gritty shales, No. 7, in a contorted synclinal axis; No. 5 is another lower limestone, in the midst of similar contorted rocks 8 near Cemmaes, and the rocks in the bay marked Porth Badric consist of similar contorted gritty shales, quartz-rock, and China stone, in the midst of which there are two bands of black shales, marked No. 6 and 6′, one of which, that between the faults *f*, *f**, contains graptolites. These shales belong to Silurian strata, and it is possible that they may be let in by faults among altered Cambrian rocks; but I am more inclined to believe that the whole series, including the limestones, is Silurian, especially as five miles further west, on the coast between Porth-yr-ysgraff and Carmels Point, there are thin irregular bands of crystallized limestone, containing Bala or Caradoc fossils, mixed with foliated shale, under conditions somewhat similar to those at Cemmaes Bay. It is therefore likely that the limestones of Llanbadrig and all the associated rocks belong to the same series; and thus it happens that it is impossible precisely to determine on the north coast of Anglesey how much of the strata are of Silurian and how much of Cambrian age, more especially as we know that east of Amlwch and south of Llanerchymedd a considerable extent of Silurian rocks have been metamorphosed into gneiss and mica schist.

Fig. 87. SECTION FROM GLOCHO ALONG THE EAST SHORE OF CEMMAES BAY.



1. Conglomerate and grit. 2, 4, 5. Crystalline limestones. 3, 6. Black shale. 7. Contorted gritty shales, &c. *f*. Faults.

Silurian rocks and granite of the middle of the Island.

The largest Silurian area of Anglesey lies towards the centre of the island (Map 78 N.W.), bounded on the north-west and south-east by the metamorphic rocks already described. Though somewhat obscured by drift, cleavage, and metamorphism, the strata as a whole presents an ascending series from the granite and fossiliferous grits of Llanerchymedd to the black slaty shale faulted against the Cambrian rocks west of Paris Mountain.

Granite.—The granite runs in a broad irregular belt, nearly 12 miles in length, across the island from the south-west coast near Llanfaelog towards Bodafon Mountain. Its greatest width is under 3 miles, near Llanerchymedd. Where best developed it forms an ordinary granite, composed of quartz, felspar, and black and silvery mica (*see* 6-inch Section, Sheet 40, line 2), but in general it is a poor and rather coarse variety, the felspar indifferently crystallized, and the mica often absent, when it somewhat resembles the kindred rock that lies amid the Cambrian strata between Bangor and Caernarvon.

The rocks surrounding and entangled in this granite are sometimes very perplexing, especially in its centre north of the Holyhead road, and on the eastern borders, where, owing to their metamorphic character, there is no sure way of determining whether the strata are of Cambrian or Silurian age. One of these doubtful masses north-east of the granite forms the quartz-rock of Bodafon Mountain, which, both in general structure and in the absence of distinct traces of stratification, closely resembles the quartz-rock of Holyhead Mountain. It probably lies in the centre of an anticlinal axis, for the undoubted Silurian rocks on the north-west dip from it, and some miles south of Bodafon the black Silurian shales of Llangwyllog overlie a southern prolongation of the rocks of the mountain. All along this side of the granite, towards Caernarvon Bay, it is more or less bordered by a belt of hard felspatho-siliceous-looking rock, sometimes faintly laminated or more clearly foliated, and rarely showing the bedding, which, as in the quartz rock of Bodafon Mountain, has often been obliterated, not by foliation so much as by a kind of induration of the fine amorphous siliceous strata. Near Bodwrog foliated portions of these rocks extremely metamorphosed are interlaced with the granite in the most perplexing manner; and a little further west, and immediately north of the Holyhead Road, there is a mass of altered rocks, about 3 miles in length, entirely surrounded by granite. Not that there is any definite boundary between them, for the foliated semi-crystalline rock is scarcely separable from and seems almost to melt into granite, rather than to skim its surface. Round Craig-yr-allor, about half a mile north of the turnpike road, the rocks often pass insensibly into an extremely foliated hornblendic gneiss, similar to that near Caerwen and the Holland Arms, near the coal field. In places the rock is so crystalline and hornblendic that it has often been mistaken for a mass of greenstone. An instance of a more complete metamorphism of the same nature occurs in the long line of highly crystalline black hornblende-rock that further north skirts the east side of the granite between Ynys-cynrig and Llanfihangel-Tre'r-beirdd.

On the west the demarcation between granite and gneissic rocks and unaltered strata is often equally obscure, so capricious are the ramifications and passages of the rocks into each other. South of Llanerchymedd it is on this account literally impossible to map the granite without including in it many streaks and patches of gneiss; and this is more the case where the granite is associated with felspathic sandstones than when it abuts on dark slate or shales, as if there were an intimate connection both in the change of these felspatho-silicious rocks into gneiss, and also in the very fact of the appearance there of the granite itself in ramifying veins; for however closely the mass of granite may abut on black shales, it is rare in the island to find good granite veins intermingled with them. For instance, near Tafarn-y-botal, south-west of Llanerchymedd (*see* 6-inch Sections, Sheet 40, line 2), innumerable granite veins ramify among the gneiss, the metamorphism of the latter being so decided that granite and gneiss are inseparable. Again, further south round Llandrygarn and Llecheyn-farwy, much of the granite has a hornblendic character, and this along with gneissic streaks occurs so capriciously that both are not only inseparable from ordinary granite, but the geological mapper constantly feels doubtful whether or not the whole should be included with the gneissic rocks. It is thus impossible to work in this country without being constantly impressed with the idea that the granite and its veins themselves are merely the result of a more thorough metamorphism than was attained in the production of the associated gneiss; that is to say, that absolute fusion of portions of the strata occurred under conditions deep beneath the surface, and that reconsolidation of these fused portions by cooling produced granite. If this be so, it will help to account for the difficulty of defining the limits of the streaks and patches of gneiss so intimately associated almost everywhere with the mass of

the granite, and also with the fact that the stratified rocks in places close upon its margin dip indifferently both towards and from it, not as they ought to do if the granite had been heaved up in the midst and had thrown off the beds on either side, but rather *as if part of the strata had been used up for the making of the granite itself.* In this case also there is an obvious reason why the general strike of the strata and of this granite is the same, to my mind far more satisfactory than to suppose that the strike has been produced by the upheaval of the granite, more especially as the strike of the Anglesey Cambrian and Silurian rocks form part of the great general system of contortion that affected North Wales before the beginning of the Upper Silurian period.

These opinions are not contradicted by anything known of other parts of the island where gneissic and granitic rock occur, and these I shall now briefly notice before proceeding to the stratified rocks. In the west of the island, near Llyn-trefwll (Map 78 N.W.), there is a small patch of granite, around which the Silurian rocks are much altered, being interlaced by numerous granite veins. North of Llanerchymedd and Llandyfrydog, amidst the Silurian sandstones and conglomerates, there are several small patches of rock coloured red in the map; they are hornblendic, and have generally been considered greenstones, but appear to me rather to be metamorphic, and somewhat of the nature of the hornblende-rock that skirts the granite on the east, and of the hornblendic gneiss of Craig-yr-allor W. of Bodwrog, more especially as they follow in the strike of some of the lines of granite that streak the strata west of Llanerchymedd.

West of Traeth Dulas there is a larger granitic mass, which stretches about 2 miles inland from the estuary. The granite is necessarily mapped, chiefly as one mass, with several smaller patches piercing the associated highly metamorphic gneissic mica-schist on the south; but in reality they are inseparable from each other, so intimately do they seem to be interlaced. A better exhibition of similar rocks lies further north, between Paris Mountain and the sea cliffs of Llanwenllwyfo. Here also the lines on the map are barely approximate, it being impossible, in quarries and little road sections, to determine how much is granite, and what are its relations to the metamorphic gneissic and quartzose rocks amid which it lies; but on the coast cliffs, where nearly a mile of section is exposed, it is more clear. At either side the metamorphic region is bounded by faults, as shown in the 6-inch section in Sheet 40, line 5, which crosses the country so near the sea that the rocks on the cliffs have been considered typical of those imperfectly illustrated in the drawing. The fault on the south is certain, black shales and thin grits being on the coast visibly thrown against the altered strata.

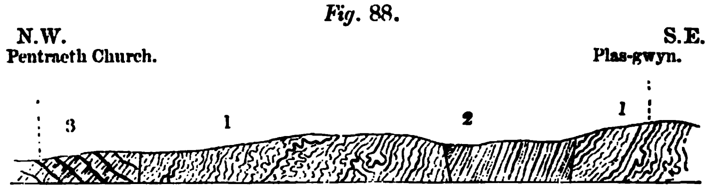
On the north the evidence of a fault, if less plain to the eye, is nearly as conclusive; for close up to the metamorphic rocks black slaty shales at high angles dip northerly, broken near their boundary, and seamed with veins of quartz; while immediately south of the boundary line, excessively metamorphic grits, also much broken and full of quartz veins, seem to strike at the slate at low uncertain angles. These beds are a kind of calcareous quartz-rock, confused, broken, and contorted, and among them veins of imperfect granite ramify. North towards Porth-lygan they pass into a kind of rough gneiss, the seeming product of metamorphosed grits, imperfectly foliated, and literally so squeezed and broken that the *smashed* fragments, as shown in section, scarcely dip steadily in any direction for a yard. On the north beach of Porth-lygan the rocks lie in very micaceous wavy foliations, dipping northerly; and in the hollow of the bay there is about 60 or 70 yards of black unaltered shale, without veins of granite, with a northerly dip of 60° or 70°. South of this there is a repetition of the same kind of micaceous schist or gneissic rock, mingled with quartz veins and highly metamorphic gritty bands, dipping northerly in undulating lines. Close to the outlier of Old Red Sandstone, seen at low tide unconformably lying on these rocks opposite Llanwenllwyfo, the micaceous and talcose schist is as red as blood, being the metamorphic representation of the fossiliferous Silurian strata. Most of the rocks are calcareous, and water percolating through them deposits patches of calcareous tuffa on the cliffs. Some of the more gritty gneissic rocks seem as if they had been altered almost to the point of fusion; and in them, but especially in the larger patches of the red flakey micaceous and talcose rocks, there are numerous small ramifying granitic veins; and some granitic masses, com-

posed of quartz and felspar, look as if contained in and entirely surrounded by metamorphic rocks. These may be, as I once considered them, the ends of veins that branch below, or else they were connected with portions of ramifying veins above, but which have been, with portions of the strata, denuded away. But it seems to me quite as probable, if not more so, that they are simply portions of the rocks that have passed the limits of ordinary metamorphism and been converted into a kind of granite by a more complete fusion of material; and this is not unconnected with the circumstance that, while here the larger masses of associated black carbonaceous shale are almost entirely unmixed with granitic veins, both these and some of the smaller beds of black shale mixed at random in the schists seem, as a rule, to have been too refractory to admit of metamorphism, perhaps partly because of the absence of lime, and the bad conducting qualities of carbonaceous rocks, heat being certainly one of the agents of metomorphism.

Silurian rocks.—The remainder of the Silurian rocks amid which the granites lie require a brief description. East of the great mass of granite in the middle of the island, near its north end, there is a belt of black slaty shales, nearly a mile in width, overlying the green and grey foliated grits of Llangwyllog. Although no fossils have been observed in them, there can be little doubt that, like the rocks on the other side of the granite, they belong to the Caradoc or Bala series, curved, to judge from the dips, in the manner shown in the 6-inch section, Sheet No. 40, line 2, and apparently dipping towards and faulted against part of the great mass of foliated Cambrian rocks near the river Cefni that lie north and west of the coal-field.

East and north-east of the coal-field undoubted Silurian rocks again appear. It has already been stated that Silurian rocks probably strike from Bangor across the Lavan Sands to Beaumaris, and concealed by deep drift, encircle the north end of the metamorphic Cambrian strata to Red Wharf Bay, where they are seen to be cut off by a fault which throws them down on the east against a part of the gneissic rocks below Mynydd Llwydiarth. From the middle of Red Wharf Bay to the south-west the strata are much dislocated; and if it be considered that the relations of the Cambrian and Silurian rocks are here too obscure to admit of certainty in the lines of fault that seem to affect them, the existence of several large and well defined north-east faults within a narrow area is rendered certain by the manner in which the Carboniferous limestone and coal-measures are affected between Red Wharf and Malltraeth Bay. It appears as if between two of this set of faults the black Silurian shales east of Pentraeth were let down between the metamorphic rocks in the manner shown in the accompanying diagram.*

Fig. 88.



1. Metamorphic rocks. 2. Silurian shales. 3. Carboniferous limestone.

This band strikes southerly, and between Plas Penmynydd and Plas-Berw it is faulted against the Carboniferous limestone, and further south, at Hendregadog, against the coal-measures. At Plas-Berw its relation to the Carboniferous and metamorphic rocks is shown in diagram (No. 96); but whether so far south it is faulted against or regularly overlies the foliated rocks on the east is quite uncertain.

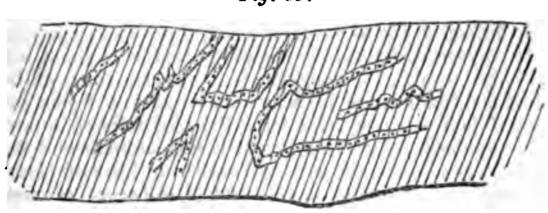
Probably the whole of this strip belongs to a low part of the Caradoc or Bala beds, although it is possible that some of the black shales near Pentraeth may be Llandeilo beds. South of Plas-Berw, where the rocks consist of shales and interstratified grits, the Bala fossils obtained were—*Orthis calligramma* and *O. elegantula*, *Stenopora fibrosa*, *Encrinite stems*, *Asaphus Powisii*, *Calymene brevicapitata*, and *Phacops apiculatus*.

* *See* also Horizontal Sections, Sheet 40, line 6.

It has been already mentioned that beyond the central granite near Llanerchymedd the dips of the Silurian rocks present an ascending section from south to north. The quartz-rock and foliated schists of Bodafon Mountain and its neighbourhood is overlaid on the north-west by black Silurian shale and grits, which stretch from thence along the borders of the granite to the south-west coast by Llyn Faelog and Cymmeran Bay. As a whole, these beds dip north-westerly from the granite at angles between 30° and 60°, and in most places yield to careful search a considerable number of the ordinary Bala fossils. It will be observed that north-east of the sands of Tywyn-trewan the recognized Silurian rocks lie in a narrow band from 1½ to 2 miles wide, between the granite and the foliated rocks of the west of Anglesey. As a general rule, on the south-east, east, and north-east of these rocks the undoubted Silurian beds dip from the metamorphic rocks as if overlying them and from the ascertained dips there is every appearance of a synclinal curve betwixt the foliated schists and the granite, but the whole boundary is so obscured by drift, from Tywyn-trewan inland and curving round to Yr-ogo-goch, near Carmels point, that unknown faults may prevail, and besides, there is no security that part of the metamorphosed rocks of this area may not be altered Silurian beds, because the fossiliferous grits do not necessarily represent the very base of the Bala series.

Where the Silurian rocks broaden, in the central part of the north of the island, the more gritty fossiliferous bed of the series is near Llanerchymedd, about 2 miles wide, dipping mostly north-west (see Map and Section, Sheet 40, line 2). By degrees the grit bands become fewer, and the strata pass into black slaty shales, shown in a considerable number of small exposures west and north of the river Alaw, these sections being, however, often so small and unsatisfactory that it is impossible always to determine whether the observed planes indicate true bedding or cleavage. In one little quarry, however, by Rhosganol near Llanbabo, it is evident that in the case of homogeneous slaty rocks the observer might easily be deceived, for in a space of about 50 feet the presence of a very thin band or of thin bands of grit revealed the excessive

Fig. 89.



contortion of cleaved strata, in a manner impossible to guess in the slaty rock, where all is equally fine and of one colour. But for the grit, the cleavage might here readily be mistaken for bedding. Notwithstanding these perplexities, enough of evidence, however, remains to show that the average dip of the country is towards the metamorphic foliated grits of the north of the island, and, for reasons already stated, it is believed that they do not pass under, but are faulted against them in the manner shown in the 6-inch section, and in fig. 77, p. 184.

Between Llanbabo and Carmels Point, at the north-west angle of the island, a band of Silurian black slaty shales, grits, and conglomerates, about 1½ miles wide, strikes north-west between the more altered strata. They are often ferruginous; and adverse dips and strikes, in lines, in rocks of different kinds, in close proximity with lodes of quartz, often give fair evidence of faults, which, to a careful observation, are especially evident round Llanfairyghornwy Mountain, and in the intricately broken rocks of the coast cliffs between Yr Henborth and Church Bay.

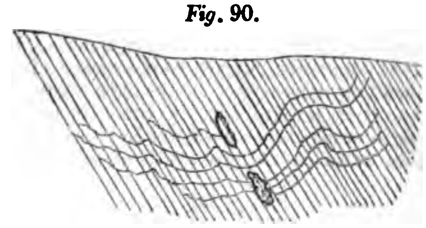
Some portions of these Silurian rocks are partially foliated in numerous small contortions, as, for instance, in one case by a footpath near Llanflewin, and the imperfectly granitic veins and dykes between the neighbourhood of Mynachty and Yr-ogo-'r Arian, seem connected with Silurian and possibly with Cambrian strata. In the concretionary half-crystalline limestone of Porth Newydd,

near Carmels Point, as already stated (p. 178), the Caradoc or Bala age of the rocks is, however, shown by the few fossils found there.

Eastward, the undoubted Silurian strata occupy a broader tract on the shore between the Old Red Sandstone, which covers them on the south, and the foliated rocks of Point Ælianus. These have already been partly noticed in describing the granitic rocks that lie among them.

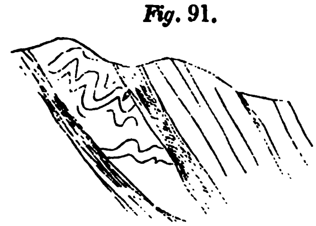
It has been already stated that black shales, interstratified with thin grits, are faulted against the gneissic rocks on the north shore of Dulas Bay. Similar slaty beds with waving dips, and disturbed by the intrusion of a branching greenstone dyke, continue south along shore to the estuary of Traeth Dulas, near which inland the dip is unknown, except in so far that the neighbouring ground seems to indicate that it is contorted, with average dips to the north, the Old Red Sandstone lying highly unconformably upon it. On the north side of the metamorphic rocks the strata also seem faulted against them. They consist of grey and black slates, dipping northerly at angles of from 70° to 80°, if the lines of apparent dip are to be trusted, for the layers are partly foliated with wavy quartz laminæ. On the north side of the Port-y-gwichiad the rocks are sometimes puzzling and in the very last geological excursion made by Sir Henry De la Beche I pointed out phenomena to him, which strongly attracted his attention. The strata there consist of soft dark blue or black slaty shale, with nodules and short thin nodular bands of grit lying in planes which, were they absent, the observer would not know whether to call planes of bedding or cleavage. But even their presence does

Fig. 90.



not remove the difficulty, for when closely examined the highly inclined lines are seen to be traversed by numerous finely contorted lines, which, but for the gritty nodules, would be considered as obscure lines of bedding. In the highly inclined lines there is also occasionally a feeble separation of different coloured laminæ, and also faint lines of foliated quartz; and this renders it still more doubtful whether or not the concretions and thin lenticular quartzose bands may not also be arranged rather in lines of cleavage than of bedding, this result being due to some peculiar influence of metamorphism. On the north side of the bay the shales are light green and brown, and contain patches and veins of quartz and wedges of quartz-rock with a northerly dip, in which are foliated lines, thus,—

Fig. 91.



Between this bay and Porth-y-corwg the strata consist of bluish-black slaty shales, interstratified with grit and beds of rudely cleaved conglomerate, the pebbles of the latter being often set in a rough slaty matrix. They are sometimes but little waterworn and are mingled with blocks and nests of impure limestone, sometimes a few inches, sometimes more than a foot in diameter. In these no fossils were observed. Their general arrangement is shown in the horizontal section, Sheet 40, line 5, and cleavage and dip nearly coincide. From their position it is evident that they belong to the same set of con-

glomerates and grits that band the Silurian rocks further west. Taken as a whole, these strata are constant, though the individual beds are scattered and irregular. The pebbles of the conglomerates are sometimes 6 or 8 inches in diameter, and, taken from different places at random, they consist of white quartz, grey quartz-rock, mica slate, green schist, jasper, purple slate, a granitic rock of quartz and felspar, with sometimes a little mica, blue felspathic trap, dark green hornblende rock, and chlorite. Most of them are rounded, but the green schistose pebbles are generally angular. It is worthy of remark that this assemblage is much the same with that found in the Cambrian conglomerates of Llanberis, and though on a hasty examination it might be supposed that the metamorphic and granitic pebbles of these conglomerates might be derived from some of the Anglesey rocks themselves, it is evident on reflection that such was not the case, the metamorphism of the Anglesey rocks having taken place after the deposition of the Lower Silurian strata, A greenstone dyke, formed of felspar and hornblende in about equal proportions, pierces the strata of the coast, running slightly across the beds, and several other patches occur further west. In Porth-y-Corwg the fault occurs which throws these strata against the more metamorphic rocks of Point Ælianus. The grits and conglomerates alternating with slaty bands, here shows the dip of the undoubted Silurian rocks to be northwards at a high angle, and striking as they slightly do against the foliated rocks that form the north side of the bay, the fault may be considered certain. West and south-west of this point, towards Paris Mountain, this fault is continued, and forms one of a set of dislocations, which, judging by similar conflicting strikes, seem to indicate that the black shales and conglomerates and the more foliated rocks are dovetailed among each other in an intricate manner, although this confusion may be partly due to the effects of mere metamorphism, which between Paris Mountain and Amlwch is so powerful that south-east of the town the rocks almost appear as if streaked with bands of felspathic trap, while a similar mass by Carreg-winllan is with difficulty separated on the east from the felspathic rocks of Paris Mountain itself.

Paris Mountain.—The rocks of Paris Mountain consist of two bands, that on the south being alone separated from the granitic and gneissic rocks by a narrow belt of black slaty shale. Between them is another band of very black shale containing graptolites, and in the midst of this, between the felspathic masses, lay that great bunch of copper pyrites which, except in certain minor branching veins, has been almost entirely quarried away. It is a difficult matter to name or decide on the origin of the hard masses that are associated with these shales. Sometimes they look like felspathic traps, and at other places they seem more siliceous and break with a flinty fracture. Sometimes they have a bedded aspect, and are streaked with blue, looking as if, when forming, the rock had been slightly intermingled with fine dark-blue mud. The whole is more or less rusty-looking or ferruginous. From a hand specimen, or even on the ground, its bedded look inclines the observer to class it with the more finely bedded felspathic ashes of Caernarvonshire, and in other spots it might be mistaken for the unsedimentary felspathic trap of Snowdon, and again in part it resembles that felspathic substance that near Penmachno enters into the composition of large lodes; but I rather incline to consider it merely a metamorphic mass, altered from an original nearly homogeneous felspathic rock, even though in accordance with the more general opinion it is coloured in the map as felspathic trap—a reading that may be legitimate, if deep under ground those sedimentary layers were partly heated to absolute fusion.

Summary of the Cambrian and Silurian Rocks.

Such is a brief account of the Cambrian and Silurian rocks of Anglesey, an account necessarily imperfect, owing to the metamorphic character of much of the country; for though it is easy to decide that the black shales and fossiliferous grits are Silurian, and though it is probable that the greater part of the more highly foliated rocks may be Cambrian, yet the limits that divide them are arbitrary and liable to doubt. The merely

stratigraphical views here advanced in the main agree with those arrived at by Sir Henry De la Beche, Mr. Smyth, Mr. Selwyn, and myself. There are, however, peculiarities in Anglesey that must not be omitted. In the greater part of North Wales the Lower Silurian section passes from the Bala limestone, through the lower part of that series to the Llandeilo flags, and in places through the Tremadoc slates to the Lingula flags, which pass into the grits, conglomerates, and green and purple slates of the Cambrian strata. All of this series is believed to be tolerably perfect in Merionethshire and the southern part of Caernarvonshire. In Merionethshire, from the Bala limestone to the Lingula flags, there is a depth of 5,500 feet of slaty beds and grit; the Lingula and Tremadoc beds themselves cannot be estimated at less than from 5,000 to 7,000 feet in thickness; and in the Llandeilo and Bala part of these great accumulations are intercalated two vast volcanic series of felspathic lavas and ashes. But much of this great array vanishes as we pass the ridge of Snowdon. There the topmost beds of the higher volcanic rocks represent the Bala limestone, and between it and the upper lake of Llanberis the whole of the Silurian series below, excepting perhaps the Tremadoc slate (the beds nearly vertical) is packed into a space scarcely greater than that occupied by the Lingula flags alone below Moelwyn and Cader Idris. The thick fossiliferous grits of Dolwyddelan, Moel Siabod, Cynicht, and Moel Hebog, have dwindled to a few hundred feet of strata that lie amidst the lowest felspathic traps of Snowdon; 6,000 feet of slaty rocks below have yielded no fossils whatever, and the Lingula beds of the passes of Llanberis and Nant Francon are barely 2,000 feet thick, while certain well-marked Cambrian masses dwindle in the same direction, for in 2 miles the uppermost Cambrian grits decrease from 1,300 to about 900 feet in thickness. In fact, each formation or subformation in succession gradually or rapidly thins away in its passage from south to north, and this is especially evinced in that remarkable diminution of the Lingula flags which occurs in 6 miles, between the pass of Llanberis and Nant Francon, and the shores of the Menai Straits, where, at Caernarvon and Bangor, they are not distinguishable, if indeed they have not thinned away entirely at the latter place, where the only known fossil near the altered Cambrian rocks is a Llandeilo species. Here, however, there is to be borne in mind the *possibility* of the so-called Cambrian rocks of Bangor being altered Lingula flags, although both texture, colour, and the structure of the country bear evidence against it; and this slight doubt must be extended to Anglesey, where similar conditions in part prevail. There no trace of Lingula flags has ever been discovered; and if the metamorphic rocks are mostly Cambrian, and the Silurian beds lie unfaulted upon them, it is plain that the Lingula flags have thinned away altogether. This is perhaps less surprising when we consider that in the only other parallel western district in Wales, that of North Pembrokeshire, the Lingula flags are of small thickness and were long undiscovered, and in

parts of Ireland they do not exist at all, while Llandeilo or Bala beds lie unconformably (as in Sutherland) on Cambrian strata. The Bala beds of Anglesey are also different from the larger part of the slaty Silurian masses of the passes of Llanberis and Nant Francon, and as a whole more strongly resemble the fossiliferous grits further south that surround Moel Hebog, Cynicht, and Dolwyddelan; and thus it becomes doubtful even if the Bala beds of the centre of Anglesey in contact with supposed Cambrian rocks are even the lowest beds of the Caradoc series. This would further add to the difficulties that surround the question, were it not that it is certain in Caernarvonshire and Merionethshire fossiliferous strata of great thickness very rapidly pass into ground barren of fossils; and it may therefore be the case, that the lower fossiliferous rocks of Anglesey represent the barren slaty rocks of the Pass of Llanberis, that lie above the Lingula flags.

Old Red Sandstone.

Though the chief object of this memoir is to describe the Lower Silurian and Cambrian rocks, it will be well, before closing the subject of Anglesey, briefly to notice the newer formations of the island in ascending order.

On the east coast the Upper Old Red Sandstone commences in Dulas Bay. A fragment of it is exposed at low tide on the beach opposite Llanwenllwyfo, resting unconformably on the red metamorphic micaceous and talcose rocks from the waste of which it was made. Further south the main mass appears lying, also unconformably, on Silurian shales, generally in the manner shown in the 6-inch Section, No. 3 of Sheet 40. It is there about a mile in breadth, and forming a bold escarpment above Traeth Dulas, it dips and undulates easterly at angles of 10°, apparently partly faulted against, but generally dipping under, the basement beds of the Carboniferous limestone. From the coast it trends southerly in a sinuous strip, lying indifferently on Silurian and Cambrian rocks, to the neighbourhood of Llangefni, where it is cut off by a small fault, and overlapped by the limestone, for beyond that point it does not reappear between the Carboniferous limestone and the Cambrian rocks south-west of Langefni. Where seen its base consists of a coarse conglomerate of quartz, quartz-rock, gneissic rocks, &c., derived from the waste of the older strata. In some cases these pebbles are embedded in a base made chiefly of the red micaceous matter of the adjacent metamorphic Lower Silurian rocks, like that in the detached patch on the shore opposite Llanwenllwyfo. The remainder consists of red and grey sandstone and cornstone (impure concretionary limestone), with thin partings of red marl, and the entire formation is about 600 feet thick. No fossils have yet been discovered in any of its beds, but, should they be found, they will probably be plants akin to those in the uppermost Old Red Sandstone of Ireland, which some persons now incline to place with the Carboniferous series.

Carboniferous Limestone.

The Old Red Sandstone is overlaid on the east by the Carboniferous limestone. On the shore of Lligwy Bay, within a short distance of the section, the base of the latter formation is so much broken and shattered that there is reason to believe that at this point the two formations are brought against each other by a fault which dies away further south. The base of the series here consists of about 200 feet of irregularly bedded sandstone and conglomerate, formed of pebbles of quartz, quartz-rock, sandstone, &c., rounded and subangular, and ranging in size from a grain of sand to 2 feet in diameter, all seemingly derived from adjacent older rocks. Associated with these are what may be called nests of hard grey limestone, sometimes a yard in diameter, and lenticular irregular beds of the same rock full of large productas, encrinites, and corals. Near the top there is a bed resembling cornstone, and the whole of these sandy beds range south in a narrow band with the Old Red Sandstone for 8 miles, from Lligwy Bay to the neighbourhood of Llangefni, where

both are cut off by the same doubtful north and south fault that passes through the east end of the town. After that they thin out, or are overlapped, for they do again appear beneath the limestone that borders the coal-field north-west of Malldraeth Marsh.

These sandstones and conglomerates are overlaid by more ordinary beds of the Carboniferous limestone, differing, however, from the greater deposits of South Wales and Somersetshire in this, that they include beds of sandstone and bands of shale, which, near the base, contain impressions of reed-like and other plants; and associated with and above these, there are thin beds of black limestone. The coast section from end to end is finely exposed in the cliffs, and the succession of strata is in general regular and but little broken by faults; but near the base on the coast, a little above the black limestone and shale, the stratification is much broken.

Fig. 92.

SECTION AT THE BASE OF THE CARBONIFEROUS LIMESTONE, LLIGWY BAY.

1. Sandstone and quartz conglomerate, with nests and lenticular patches of fossiliferous limestone.
2. Black shale and limestone, with plants.
3. Grey limestone, about 20 feet.
4. Thin rubbly limestone, about 12 feet.
5. Limestone in great broken brecciated blocks, with quartz pebbles, corals, &c., overlaid by limestone and sandstone.

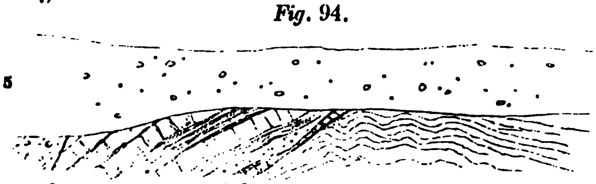
On the east coast the limestone occupies a tract of about 6 miles in length, between Lligwy Bay and Pentraeth, and from 2 to 4 miles broad between the Old Red Sandstone and the sea. With the exception of the junction beds mentioned above, I have elsewhere described it as "fossiliferous "limestone, chiefly grey, with occasional black and reddish beds, and thin "bands of sandstone and conglomerate near the middle, containing pebbles "of quartz, quartz-rock, black slate, jasper, and other metamorphic rocks, "and impressions of plants." These conglomerates are quarried for millstones. As a whole, from north to south and west to east the strata undulate at low angles towards Pentraeth, where they are more disturbed. A fault passes across the middle of the strata from Penllech on the shore to the Old Red Sandstone, being a downthrow on the north of about 350 feet, by which the millstone bed is repeated, as shown on the 6-inch section, line 6. At Pentraeth, on either bank of the stream, the high dip of the beds indicates an anticlinal axis, and the rocks finally dip against the metamorphic foliated schists at a high angle, clearly indicating a fault. All the beds are, in general terms, fossiliferous, containing *productas*, *spirifers*, *encrinites*, *corals*, &c., common everywhere to the Carboniferous limestone. In this part of Anglesey the topmost beds are not reached, for till we get to Malldraeth Marsh there is no indication of an overlying millstone grit. The total thickness where crossed by the section is about 1,100 feet thick, and occasionally on the flat-topped hills formed by the highest continuous beds, upright natural pillars of limestone remain, attesting the former presence of higher beds, of which these are the relics. The same rocks are often almost bare of soil, seamed by numerous gaping joints, so widened by the carbonic acid of the rains that the pedestrian must give good heed to his feet in traversing the terraces and bare table-land. The pillars themselves are, I believe, the result of the same process of the dissolving of lime by the agency of carbonated rain-water

Fig. 93.

and the topmost beds being absent no man can tell how much has disappeared.

In direct continuation of the limestone south-west of Llangefni the formation forms a long narrow strip on the north-west side of the millstone grit, which it underlies. Here also the beds are occasionally black near the base, but chiefly grey, and they include beds of sandstone. The sandstones and conglomerates that form the base of the series are, however, absent, and there is reason to believe that, passing south-west, the beds are gradually overlapped in succession, the higher strata by degrees intruding in the foliated rocks below. Where crossed by the section (No. 1, Sheet 40, line 3) the limestone is only 450 thick. In the railway cutting several years ago it presented the following section:—

Fig. 94.



1. Green laminated schist, Cambrian.
2. Black limestone.
3. Calcareous shale and limestone.
4. Conglomerate of Millstone grit.
5. Boulder drift.

f. A fault, and *f*× a doubtful fault.

A little further south it thins away altogether, and the millstone grit lies on the altered rocks of Bodorgan. To the coal-measures I shall by and by return.

The east point of Anglesey is formed of another tract of Carboniferous limestone, uniting by the intermediate steps of Puffin Island and the Great Ormes Head the larger area west of Red Wharf Bay with the great limestone ranges of Flintshire and Denbighshire. Its south boundary is much obscured by limestone gravel, but its general structure, the black limestone and shale at its base, and the beds of sandstone and conglomerate it contains near the east point, show it to represent pretty fully the strata west of Red Wharf Bay. At Penmon it is a brown crystalline dolomite, and a little further east it is pierced by a short felspathic dyke. It was from the beds of Penmon that Caernarvon Castle was partly built, and from the same quarries, and at Benllech, north of Red Wharf Bay, the great blocks of stone were taken for the construction of the Menai and Britannia bridges.

Limestone Series of Menai Straits.—A third broad band of Carboniferous limestone lies on both shores of the Menai, between Bangor and the coast of Anglesey, opposite Caernarvon, forming one area, through which the waters of the straits flow. On the Caernarvonshire side the Carboniferous beds are thrown against Cambrian rocks and quartzose porphyry by one of those great north-east faults which affect the Palæozoic rocks from Shropshire to Anglesey, and which are so closely related to their average strikes. Here, south-west of Bangor, the strata consist of gritty white and sometimes red sandstones, conglomerates, and shales containing Carboniferous plants, and bands of limestone with productas, corals, &c., the various kinds of beds wedging in and out among each other so irregularly that even on a large scale of map it would probably be very difficult to separate them. With various undulations, as a whole they dip south-east, at angles from 10° to 15°, except near the fault, where this dip is often suddenly reversed. At the base of the cliff, for some distance on either side of the Menai Bridge, there are beds of red shale or marl, different in character from the Old Red Sandstone, and intermingled with sandstone and quartz conglomerates of a Carboniferous character. These cross the straits and dip under the limestone of Plas Newydd, both dipping about 15° southerly, and at the base of the red shale lie beds of grit and conglomerate.

On the Anglesey side of the straits the Carboniferous rocks are about 1¾ miles broad, ranging from Llanfair-pwllgwyngyll near Menai Bridge to Traeth Melynog, opposite Caernarvon. They lie upon the gneissic rocks highly uncomformably,

dipping south-east at angles of about 4° or 5°. The base is generally very obscure, being covered by drift clay with boulders; but lying on low ground under a marked escarpment, it is considered probable that it consists of shales, bands of limestone, marls, and sandstones, generally (though varying) like those of Plas Llanfair and the Menai Bridge, and of the lower beds of the limestone series in Lligwy Bay and on the coast towards Puffin Island. The main mass between the escarpment and the straits consists chiefly of grey and occasionally of reddish and black limestone, with the usual fossils, and occasional bands of sandstone and calcareous conglomerate; and on the south, opposite Caernarvon, these are overlaid by red marly shales, dipping south-east at low angles, so bright in colour that in an old map I have seen them coloured as New Red Marl. The same strata occur on the opposite shore, where they consist of soft red and green marl, with layers of sandstone, dipping south-east about 5° against the granitic rocks of Caernarvon. They may be seen on the shore and in brick pits at Y-Rhadd-dir, where it is said they bored 60 yards through red marl and layers of sandstone in search of coal. The same red beds are underlaid at Llanfair-is-gaer by a coarse conglomerate composed of pebbles of Carboniferous limestone and chert, Cambrian grit, quartz porphyry like that of the neighbouring masses, black slate or shale (rare), older conglomerates rounded into pebbles, greenstone, various other felspar porphyries of Caernarvonshire, and a red one in great quantities, the native place of which is unknown. The whole has a shingly beach-like aspect, and doubtless was once the beach of an old Carboniferous sea that washed a land formed of highly disturbed Cambrian and Silurian rocks, of which the crystalline boss against which the conglomerate is faulted formed a part. As already stated, five small greenstone dykes penetrate and slightly alter the rock. It is succeeded by beds of red conglomerate, sandstone, grit, and dolomite at Dinas on the shore, beyond which are the more ordinary beds of the Limestone series. A small outlier of Carboniferous limestone lies on the hill by Coed Helen across the river from Caernarvon, but its precise stratigraphical position is unknown. When the country was mapped, it was considered by Mr. Selwyn and myself that these overlying red marly beds and the coarse conglomerate of Llanfair-is-gaer belonged, like the lower red marly strata near Menai Bridge, to the Carboniferous series. Lying also above the highest known limestone beds of the straits, it was thought that it might probably form part of the Coal-measures, but on the other hand it is not impossible that hey may belong to some portion of the very obscure Permian strata which I discovered lying unconformably above the Coal-measures of Malldraeth Marsh, some years after the publication of a first series of the maps.

Coal Measures.

Between 3 and 4 miles from the straits, and resting on the limestone, lies the little coal-field of Malldraeth Marsh. Together they lie in a hollow of the older rocks, and by help of a fault that bounds it on the south-east, the coal-field has been preserved from complete denudation. This fault is shown in the section, fig. 90, and is a downthrow on the north-west of about 2,300 feet.* Together with the Permian strata these Coal-measures form the entire sub-strata underneath Malldraeth Marsh. The length of the coal-field is 9 miles from the neighbourhood of Hirdrefaig to Malldraeth Bay, where it passes out to sea under the sands, which are covered at low water. Its breadth is about 1½ miles. The whole forms a marshy tract, which, excepting the edge of Millstone grit, is almost entirely below the high-tide level, for the river is banked nearly to the north-east end of the coal-field, to prevent the daily overflow of the tide. The river itself, together with some minor sluggish streams and stagnant pools, soaks down into the Carboniferous and Permian beds, which generally dip south-east towards the boundary fault, and so saturates the porous strata with water that its drainage into the coal pits forms a serious difficulty in the working.

The utter absence of surface sections, the small number of coal pits, and the imperfect nature of the records that have been kept of most of the shafts and borings, render it impossible to make out accurately the details of the structure of this coal-field, small as it is. The part best known is in the neigh-

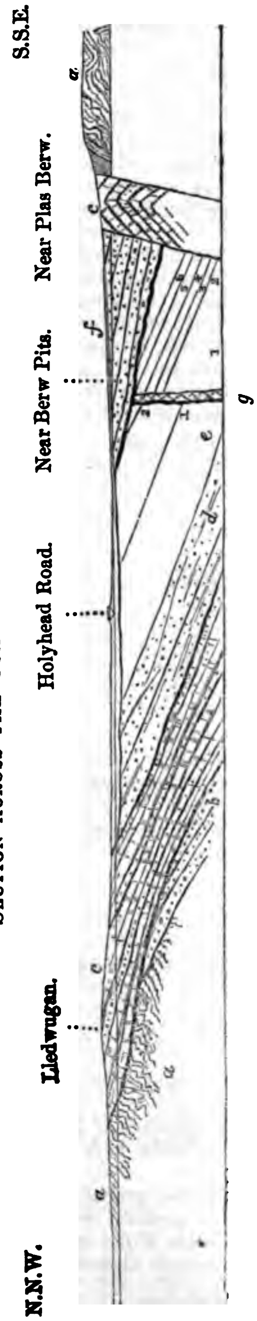
* See p. 204.

bourhood of the Holyhead road, at the Penrhyn and Berw pits. Here, as far as is known, it seems likely that the thickest Coal-measure strata and the greatest number of beds of coal occur, the result, probably, of faults throwing in certain beds not found elsewhere in this area.

The following section shows the general arrangement of the strata in and surrounding the coal pits :—

Fig. 95.

SECTION ACROSS THE COAL-FIELD OF ANGLESEY.



Scale, three inches to a mile.

a. Silurian and Cambrian metamorphic rocks.
b. Old Red San dstone.
c. Carboniferous Limestone.
d. Millstone Grit.
e. Coal-measures.
f. Permian strata.
g. Greenstone dyke and fault.

On the north-west of the section at the base lie foliated Cambrian schists, and between them and the Carboniferous limestone the hypothetical position of the Old Red Sandstone and basement Carboniferous conglomerate are indicated, for, a little further north-east, these are overlapped by the limestone, and if their strike be continued underneath the surface they would lie somewhat as shown in the section. Above them lie the ordinary beds of the Carboniferous limestone, and these are succeeded by the Millstone grit and Coal-measures dipping south-east about 20°, this inclination being known by the beds of Millstone grit on the edge of the coal-field, and for the Coal-measures, which are everywhere concealed under the marsh, by the fall of the strata in the neighbouring coal pits. The Millstone grit is about 400 feet thick. It consists of yellow sandstone and conglomerate, and contains a bed of coal from three-quarters to one yard thick, heretofore worked at Glantraeth, and which I have therefore called the Glantraeth coal. Above the grit there are seven other beds of coal, distinguished by the miners in the ordinary Coal-measures, and I am not aware that any more are known in the coal-field. The following appears to be the order of the entire Permian and Carboniferous series of Anglesey, made out as low as the three-quarter coal from the Berw coal pits, and below that, gathered from imperfect data in the surrounding country. The section between the three-quarter coal and the Millstone grit is therefore doubtful, and there is also considerable doubt both as to the position of the Glantraeth coal in the grit and the thickness of sandstone above it. The precise details also of minor variations of the strata in the shafts have not always been preserved, various beds having been apparently sometimes massed by the miners.

SECTION OF THE BERW PITS AND PROBABLE POSITIONS OF THE UNDERLYING STRATA.

		ft.	in.	ft.	in.
Superficial detritus.	Clay and sand	24	0		
	Turf	3	0		
	Gravel	2	0		
				29	0
Permian.	Red sandstone, conglomerate, and marl	-	-	195	0
Coal-measures.	COAL ("Glo pux") "lying in lumps;" unworkable	9	0		
	Shale	51	0		
	COAL	3	0		
	Shale	63	0		
	COAL	4	0		
	Soft shale	24	0		
	Hard white rock (Sandstone)	12	0		
	Hard shale	12	0		
	Hard red rocks (Sandstone)	27	0		
	COAL, irregular ('Glo pux")	2	0		
	Hard shale	36	0		
	Soft shale	7	0		
	COAL	6	0		
	Soft shale	12	0		
	White sandstone slightly tinged with red	60	0		
	Black shale	18	0		
	COAL, with 6 inches Cannel on top (¾ Coal)	1	8		
	Sandstone and shale, probably about	300	0		
	COAL (probable position of Berw-uchaf Coal, in three beds with thin partings)	7 to 8	0		
	Shale and Sandstone, probably	650	0		
	COAL, probable position of the Glantraeth Coal in Millstone grit	2 to 3	0		
	Millstone grit, bottom division	200	0		
				1,508	8
Carboniferous limestone at Llangristiolus				450	0
				2,182	8

It is probable that about 200 feet of rock above the Glantraeth coal belongs to the Millstone grit.

Where crossed by the section, none of the above coals crop to the surface under the marsh, except the Glantraeth and probably the Berw-uchaf coals. The remainder, from the 6-feet coal upwards, belong to a higher part of the series, thrown in by faults *which occurred before the deposition of the Permian strata*, against the base of which the coal beds crop. A greenstone dyke, shown in the section, rises in one of these faults, but does not penetrate the overlying Permian strata.

In the north-east angle of the coal-field, west of Llanfihangel Esgeifiog, only a low part of the Coal-measures is believed to exist, including, probably, the Glantraeth coal, and possibly a little of the 6-feet coal and the coal of Berw-uchaf; but the information was too imperfect to make this certain, though the most northerly of the east and west faults is said only to be a downthrow on the south of 7 yards. If this be so, and the ground remain untroubled, the 6-feet coal may underlie the Permian rocks north of the fault for a little space, and the Berw-uchaf coal, if constant, may rise in the marsh. Three east and west faults, all downthrows on the south, cross the Holyhead road (*see* Map 78 S.W.), and are said to be cut off by a north and south fault which passes from the great north-east boundary fault near Plas Berw towards the 16th milestone, and being a downthrow on the east may perhaps be a continuation of the fault that passes through Llangefni, throwing the Carboniferous limestone against the foliated rocks on the west; but the evidence of both is lost in the marsh. Between the east and west faults at the Penrhyn pits, the north and south and greenstone or rock-faults, and the great boundary fault, there is a triangular space crossed by the section in which the upper coals of this area lie beneath a thick covering of Permian strata. Between the two northerly faults, which are only about 55 yards apart, the 4-feet coal is said to have cropped against the Permian beds near the surface, and either there or between the middle fault and that to the south the 6-feet coal was said to be worked at a depth of 60 yards. The strata are said here to lie flatter than they do further south at the Berw pits. The southern of the east and west faults is said to be a downthrow on the south of 69 yards, but this is doubtful as far as I know; and the greenstone or stone fault is a downthrow of 154 yards on the east, where it curves round to the south, as marked on the map, and of 69 yards, where it strikes east and west by the pits in the lines which represent its course beneath the Permian strata. In the Berw pits within this space shafts have been sunk and the coals worked, dipping south-east in the manner shown in the section. Only the ¾ coal rises west of the stone fault, where it is believed to abut on the bottom of the Permian strata, and though unproved, it seems probable that the Berw-uchaf coal, uncovered by Permian strata, may crop somewhere under the marsh. This is, however, very uncertain north of the rock fault, as it may be that the ¾ coal is entirely cut out by these faults, throwing the upper measures in the north part of the field exclusively against the strata that lie between the Berw-uchaf coal and the Carboniferous limestone.

It is reported that a north-west fault runs from the boundary fault west of Berw-uchaf towards the greenstone fault in the direction of Llangristiolus, being a downthrow on the north-east, and throwing in some of the higher strata, but its amount I was unable to ascertain. It seems to me, however, that there must be a fault nearly in the position indicated on the map, for west and south of it only the Berw-uchaf coal and the lower minor beds are known, and, indeed, all that is known of this part of the coal-field would seem to indicate that the smaller faults west of the boundary fault having occurred before the Permian epoch, the upper coals in this part of the coal-field were denuded away before the deposition of the Permian strata. The sinkings at Berw-uchaf confirm this. In these the 8-feet coal was passed through at a depth of under 60 yards, a little north-east of the pool marked in the map. The section was as follows:—

"Alluvium" - - -	12 yards.
Red Sandstone (Permian) -	20–25 „
Coal-measures - - -	20 „
Coal in three parts - - -	8 feet, about 2 feet good.

Here below the Permian rocks (against which it is supposed the 8-feet coal crops) there are only 60 feet of strata above the 8-feet coal. Judging roughly,

from the position of the probable outcrop of this coal with regard to the Millstone grit and the Glantraeth coal, it is considered probable that, as the beds lie flatter than at the Berw pits, there is not space sufficient for the three-quarters and higher coals to come in between the Berw-uchaf pit and the boundary fault. It has yet, however, to be proved that this is the case. Further south the Glantraeth coal, about a yard in thickness, has been worked in the neighbourhood of the railway.

Permian rocks.

Though the Permian rocks are nowhere seen on the surface, their existence in this district may nevertheless be considered certain. The red rock that covers the eastern half of the Coal-measures is perfectly known to the miners. It has been sunk through north of the Holyhead road in the coal pits there. Its thickness at the Berw pits is ascertained to be 195 feet, dipping south-east like the Coal-measures, but at a lower angle. Red rocks of the same kind were also passed through in a trial boring west of the greenstone fault. At the Berw-uchaf pit it is about 25 yards thick. About 1½ miles further south, near the road that crosses the road from Llangaffo, a trial was made and red sandstone found, but in the western half of the coal-field about the Glantraeth pits, both old and new, shafts and borings after passing the alluvium, &c., sank at once into Coal-measure shales. When I saw the red rocks that had been brought up from the upper part of the shafts, I at once recognized lithologically their Permian character in the red sandstones and occasional angular conglomerates with blotches and partings of red marl. The inference was further confirmed by information that some of the beds of coal crop up against the base of these red rocks, and that the minor faults, including that filled with a greenstone dyke, do not penetrate the unfaulted red sandstone. It thus evidently lies unbroken and unconformably upon the faulted and denuded surface of the Coal-measures and greenstone below; and therefore there seemed no doubt that the unconformable strata must be Permian, especially since they are quite unlike any part of the New Red Sandstone, while similar rocks overlie the North Wales coal-field south of Wrexham. The existence of this outlying patch of Permian rocks in a situation so unexpected is interesting, especially as it is certain that neither it nor the coal-field would now exist but for the north-east boundary fault.

The Boundary Fault.—Between Berw-uchaf and the sea the great fault, being a downthrow on the north-west, causes the Permian and Coal-measure strata to abut on Cambrian rocks; but north-east of Berw-uchaf the amount of the general throw decreases, and between the two faults a strip of Carboniferous limestone comes in, abutting on Permian and Silurian rocks in the manner shown in the section. There can be no doubt that the limestone underlies the coal-field, for the outlier at Plas Llangaffo proves this, and the amount of the throw of the great boundary fault may be thus approximately obtained. Where crossed by the section near Plas Berw, the western fault is a downthrow on the north-west of 2,300 feet. The eastern branch, throwing the limestone against the Silurian rocks, is a downthrow in the same direction of uncertain amount, but probably not exceeding 400 or 500 feet, estimating the thickness of this limestone to be approximately the same with that on the opposite side of the coal-field.

With regard to the coal-field, I repeat, that but for the great boundary fault throwing down the rocks so deep, neither Coal-measures nor Permian rocks would have been preserved from the average plaining effects of old denudations, probably marine. Had the Coal-measures not been preserved by this fault, their existence at any period in the Anglesey area would perhaps never have been dreamed of by the generality of observers, for what, in consequence of the fault and the denudation of the soft Coal-measures, is now the valley of Malldraeth Marsh, would without the fault have shown only a broad continuation of the limestone that lies between Pentraeth and Lligwy Bay; the over-

lying strata of Coal-measures, that once overspread the limestone, having in that area been removed by denudation. As the limestone may be safely inferred to underlie the coal-field, so there can be no doubt that it once extended further to the south-east, the little outliers of sandstone of the limestone series at Plas Llangaffo and Ty'n-twr indicating that it once extended across the schists and joined the limestones of the straits. The Coal-measures and Permian rocks now abutting on the fault also necessarily extended in that direction, how far it is impossible to say, but judging by the form of the ground, the fragmentary patches of limestone, and their scarped edges, it would not be too much to infer that the whole of Anglesey and at least all the low ground of Caernarvonshire, and perhaps a great deal more, were once covered by Carboniferous strata. Such great denudations are not the exception but the rule.

CHAPTER XXV.

Llandovery Rocks, Tarannon Shale and Denbighshire Grits of Caernarvonshire, Denbighshire, and Montgomeryshire.

General Description.—The lower Silurian rocks are bounded on the east by Lower Llandovery rocks, the Tarannon shale, and Denbighshire grit, the last of which is overlaid—from Conway to Llanbadarn-fawr* in Radnorshire—by the Wenlock shale, of which it forms a subordinate part.

These form a border on the east to the great Lower Silurian district of Merionethshire and Caernavonshire, and also surround the Berwyn Hills. To finish the subject for the present, it will be better to give a slight sketch of this part of their range.

Between Aran Mowddwy and the south side of the Berwyn Hills the section in column would be as follows:—

Wenlock shale } Wenlock beds.
Denbighshire grit }
Tarannon shale.
(*Upper Llandovery or Pentamerus beds absent.*)
Lower Llandovery beds.
Caradoc or Bala beds.

Near Conway the members present are—

Wenlock shale } Wenlock beds.
Denbighshire grit }
Tarannon shale.
(*Upper and Lower Llandovery beds absent.*)
Caradoc or Bala beds.

Nowhere in this district is there any visible unconformity between the Bala beds and the Lower Llandovery rocks, and the

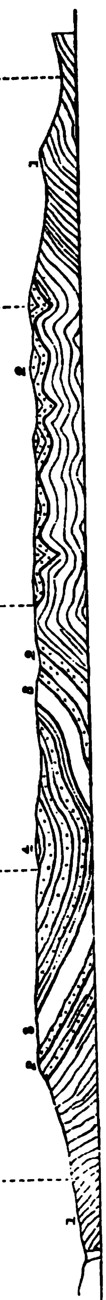
* Between Rhaiadr and New Radnor.

latter are therefore most conveniently included as part of the Lower Silurian series.*

The Lower Llandovery rocks of this area may be dispatched in a few words. Between Conway and the country east of Bala Lake they are unknown, partly, it is probable, because they have thinned away in their continuation to the north, but the Tarannon shale and Wenlock strata resting unconformably on the underlying formations, the Llandovery beds may be overlapped. Following the edge of the Tarannon shale southward, the Lower Llandovery rocks first appear in a very attenuated form about 5 miles south-east of Llangower near Bala Lake, on the south side of a fault that crosses Cefn-bwlan from east to west. They consist of hard beds of grey grit which thicken by degrees on their southward strike and soon become intermingled with beds of shale. Throughout all their range of about 20 miles in a direct line to the river Tarannon,† they run in a narrow band, the lower edge of which is rarely more than half a mile from the shale, their thickness rising up to 500 or 600 feet. But east of the great synclinal curve by the Tarannon river the series increases to about 1,500 feet in thickness, and is repeated in a series of rapid contortions across miles of country between Carreghir and Bryn-crugog, in the manner shown in the following diagram.

Fig. 96.

SECTION ACROSS THE LOWER AND UPPER SILURIAN ROCKS SOUTH OF LLANBRYNMAIR, MONTGOMERYSHIRE.



1. Upper part of the Bala beds.
2. Lower Llandovery beds.
3. Tarannon shale.
4. Denbighshire flags and shales (Wenlock).

* For an account of the palæontological relations of these strata to the Lower and Upper Silurian rocks, see my Anniversary Address to the Geological Society, 1863.

† Six miles N.N.W. of Llanidloes, in Montgomeryshire.

East of this they disappear under the shale near a house called Dol-friog, perhaps by thinning out, perhaps by overlap. Everywhere they seem to pass regularly and conformably downwards into the underlying Bala beds, in the manner shown in the diagram, although this conformity is probably either accidental or deceptive, for near Llandovery, in Caermarthenshire, unconformity was detected by Mr. Aveline. Neither can the eye detect any unconformity between the Lower Llandovery beds and the overlying Tarannon shale, but unconformity may be inferred, from the close connexion of the latter with the Wenlock series, for the Tarannon shale in many places lies indifferently on different horizons of the Lower Silurian strata, besides that a member of the upper series, the Upper Llandovery beds, is absent in this part of North Wales. If present it would lie between the Lower Llandovery beds and the Tarannon shale, as shown in the table at the beginning of this chapter.

The apparent conformity between the Lower and Upper Silurian rocks of Merionethshire and Montgomeryshire doubtless arises from the circumstance that during the deposition of the Upper Silurian rocks, the Lower strata of this particular area had been but slightly disturbed; and at a later date the whole having been bent and contorted together, the strike of the Upper and Lower Silurian rocks here to a great extent coincides, although between them there is a great break in direct sequence, marked especially by the absence of the Upper Llandovery rocks.

Beyond a few rings of encrinites I do not remember that in this country any fossils have been observed in the Lower Llandovery beds, though near Builth and Llandovery, where they again appear, they are higher fossiliferous.

The Upper Llandovery or Pentamerus beds being absent, the Tarrannon shales in this district succeed the Lower Llandovery rocks. In mineral character they are, for the most part, very persistent, and consist of fine smooth slaty strata, grey or light blue, occasionally slightly sandy, and alternating with purple bands. They were first mentioned by Professor Sedgwick, who, I believe, called them "paste rock," from the circumstance that when decomposed they formed a fine muddy paste. No fossils have been found in them in North Wales, and they are interesting as showing how a new division, 1,000 to 1,500 feet thick, may be discovered between strata that were previously supposed to lie on each other without any break of succession. Till attempted by Mr. Aveline, no one thought of mapping these beds; and the proof he adduced in South Wales that they lie unconformably on the Lower Silurian rocks, and are overlaid transgressively, in much smaller degree, by the Wenlock strata, shows how necessary it is to map every possible formation in detail, before we can arrive at just conclusions respecting either the completeness or the fragmentary nature of the succession of strata; for here an independent sub-formation, previously unsuspected, appears; and though in itself it as yet shows no fossils in North Wales, in

thickness it is greater than the Wenlock shale at Wenlock, and probably occupied as long a period in its deposition.

Tarannon Shale.—Near Conway the Tarannon shale by unconformable overlap rests on a horizon of Lower Silurian rocks not much higher than the Bala limestone. From Conway to Llanbedr, about five miles south, these shales form a narrow band at the base of the Denbighshire grits, thrice interrupted by faults, which are downthrows on the east. From Llanbedr all up the vale of Llanrwst and across the country beyond Pentre Voelas they are never seen. In the valley of Llanrwst they may underlie the alluvium, but it is more likely they are cut off by a large fault which, it is supposed, under the alluvium, throws the Denbighshire grits against beds pretty low in the series. Between the Vale of Llanrwst and the country four miles east of Yspytty Evan and Pentre Voelas, except in one spot, they are nowhere seen in their usual position between the Bala beds and the Denbighshire grits; and it is presumed again they are cut off by faults, being downthrows on the north-east, west, north, and north-west. The evidence for the existence of these faults lies chiefly in the fact that the Tarannon shale is so nearly conformable with the Denbighshire grits (or base of the Wenlock beds) that there is no reason to suppose it is anywhere suddenly overlapped. The rocks of the country are, however, much obscured by drift. Beyond this point they follow the winding western outcrop of the Wenlock beds, in a narrow band almost unbroken, from Merddwr, east of Pentre Voelas, to Llanddewi-Ystrad-enny, north of Builth in Radnorshire. First they strike east between eight and nine miles, and then bend suddenly round near Derwen at what may be called the north-eastern angle of the great Merionethshire anticlinal curve. Here for about half a mile they are cut out by two faults that meet in the form of a V and let in the Denbighshire grit, so that it is brought in immediate contact with the Bala beds. The Tarannon shale then strikes south-west for 8½ miles, when its continuity is broken by a powerful fault, which, on the north-east, as shown on the map, throws the whole Upper Silurian country, so to speak, forward more than a quarter of a mile, and which, if the result of a vertical movement, indicates a displacement of about 1,850 feet, the dip of the strata being between 45° and 55°.

The dislocation mentioned above is about 3½ miles north-east of Bala, and from this fault the same shales range a little west of south for nearly 30 miles to the high moorland of Tarannon, whence (being well developed there) these shales derive their name. Throughout all these long ranges the dip is so high that they strike straight across the country over hills and across valleys, being generally not more than an eighth of a mile wide, and rarely exceedingly half a mile. In Montgomeryshire, on and near Tarannon, the rocks being much contorted and well denuded (see Diagram No. 97), wind about and run up the valleys of Nant-yr-Eira and Afon-Cwm-llwyd; and further north, from half a mile to a mile in width, they follow all the windings of the Wenlock shale, far beyond our present district, to the country near Builth.

Denbighshire Grit and Wenlock Shale.

The Tarannon shale is succeeded by the more commonly recognized Upper Silurian rocks, which in Flintshire, Denbighshire, Merionethshire, and nearly the whole of Montgomeryshire, consist of various representatives of the Wenlock shale, sometimes still preserving a shaly form; sometimes, as at Llangollen, consisting of truly cleaved slates and flagstones; and again, at its base in the west, represented by a vast thickness of interstratified shales and grits, named by Professor Sedgwick the Denbighshire grits and flagstones. A glance at the map will show their range in our present area. On the north, of enormous but unknown thickness, the Wenlock series forms the whole of that broad hilly tract that extends for 40 miles from the shores of Denbighshire to beyond

Llangollen, and from the Vale of Conwy to the mountain limestone of the Vale of Clwyd. East of that valley, the same formation forms that long mountain range of which Moel Fammau forms the highest point. In the northern part of Denbighshire, of which Llansannan is the centre, few great high roads penetrate the Wenlock shale districts of the country; the hills, rarely bold, but high and steep, are yet of incessant recurrence; and thus it is that to strangers it forms the least known district of North Wales. In the 1-inch maps, numerous arrows pointing in all directions attest the great amount of contortion that the strata, chiefly of rubbly shale, have undergone; a circumstance, joined to their thickness, that accounts for the great area which they cover. Between Conway and the neighbourhood of Builth, a distance of 75 miles in a straight line, the Denbighshire grits, resting directly on Tarannon shale, form the western edge of the Wenlock formation. But thick as these grits are, in places at least 3,000 feet, and broad as the area is which they occupy, they form but a local variety of the Wenlock formation, and apparently, where the grits thin and disappear, instead of being overlapped by the shale, they rather pass by lithological gradations gradually into strata of a shaly character. From the quantity of felspathic grains that enter into their composition, I am, indeed, inclined to infer that part of the mountain region of North Wales, between Conway and Cader Idris, formed land (very different from its present form), which contributed locally to form these strata by the waste of the felspathic lavas and ashes that form a distinguishing feature of the Lower Silurian rocks of North Wales. From east to west, and from north to south, the coarser gritty beds gradually disappear, the farther we recede from the larger centres of the Lower Silurian volcanic rocks. Near Montgomery and Welshpool they are unknown at the base of the Wenlock shale, though igneous rocks are near; south of the Berwyns they do not extend as far east as the base of the shale near Llanfyllin; and on the north of the Berwyns they are unknown. Neither north of Llangollen do they appear between the Tarannon and Wenlock shales that skirt Cyrn-y-brain and Carn. The sand has passed into mud going eastward; and the position of the above-named bosses of Caradoc or Bala beds leads to the inference that the contorted Upper Silurian strata bordering the Vale of Clwyd on the west, are not far from the base of the Wenlock shale, and in part represent the true Denbighshire grits that skirt the Vale of Conwy.

Vale of Conwy, &c.—East of the Conwy, nearly opposite the town, the grits, much obscured by drift, occupy a space about three-quarters of a mile square. Their northern boundary strikes north-easterly, and (if there be no intervening fault) lies not more than 800 feet above the calcareous sandstone that here represents the Bala limestone. This is a point of interest, for in the Bala country more than 4,000 feet of rocks lie between the limestone and the Denbighshire grits; and, making every allowance for thinning of the Bala strata, the difference helps to mark the extent of the overlap and unconformity of the Upper on the Lower Silurian rocks of North Wales. Opposite Conway they dip a little east

of south at an angle of 55°, where on the east they are bounded by the Carboniferous limestone, which is probably thrown against them by a fault; and on the west the Tarannon shale is cut out, and the Denbighshire grits strike under water as if abutting on the Bala beds of Conway, helping to prove the continuation in the estuary of the line of fault that passes down the brook by Pentre-felin.* This fault being a downthrow on the east, casts the grits and shales forward to the north about three-quarters of a mile, and the amount of the throw is probably about 2,000 feet.

On the hill immediately south of Conway, the base of the grits, resting on a narrow band of Tarannon shale, strikes towards Gyffin, and from thence dipping east at angles between 10° and 35°, they pass southward by Y-Ro to Caerhun, when the western boundary is lost in the alluvium of the Conwy. There with their associated shales the grits form most of the hilly ground that stretches from Conway to Caerhun, half way up the river to Llanrwst.

Between the neighbourhood of Caerhun and Hendre-went† the west boundary of the gritty series is (under the alluvium) probably thrown down on the east against slaty and igneous rocks of the Bala beds, by the fault which there is reason to believe runs right down the bottom of the valley. East of the Conwy, at Pentre-felin near Llansantffraid-glan-Conwy, the Wenlock shale is thrown against the gritty beds by a downcast fault on the north-east, but within 2 miles of the river the dislocation passes into the shale and is lost; and from thence the upper boundary line, which is rarely very definite, passes south, close by Eglwys-bach and Llanddoged and Llanrwst, where it rapidly curves to the south-east. With sundry undulations of the strata, which are most numerous near the north, the whole dips eastward under, or rather passes upwards into, the Wenlock shale; and, indeed, in all the tract that borders the Conwy, from top to base, shales in many places predominate.

South-east of Llanrwst the Denbighshire grits or flagstones occupy the whole of that barren and heathy range of hills that trends from the crags of Moel Saesiog by Mwdwl Eithin to Llechwedd near Cerrig-y-Druidion.‡ Though much of the ground is deeply covered by drift, there is little doubt that the lower boundary between Llanrwst and Merddwr, east of Pentre Voelas, is faulted against the Bala beds; but beyond this point to the angle of the Merionethshire anticlinal curve, near Derwen, the lower boundary is tolerably distinct. On the range of hills mentioned above, the gritty beds, though interstratified with blue slaty shale, are often thick, and stand boldly out, their massive character having more strongly enabled them to resist denudation, thus giving rise both to the height and comparative ruggedness of the country. Here also, being partly repeated in three undulations, they spread across a space of 6 miles in breadth from Garn Brys to the grey rocks of Craig-y-llwydion beyond Llyn Alwen.

Approaching the sharp bend of the Merionethshire anticlinal curve, near Derwen, the undulations of these strata die out, and the total thickness of the grits on the banks of the river Alwen is compressed into a space of half a mile in breadth; and the beds now dipping steadily south east from 30° to 50° must be about 1,500 feet thick. South of the Alwen they again widen out and occupy the chief part of the surface enclosed between the two great north-east faults and the fault that runs north-west from Llandderfel, near Bala. In the southern part of this area they lie in the form of a low synclinal curve, the east end of the grits being thrown by the great fault against an upper part of the Bala beds. A small patch overlying the pale-coloured Tarannon shale also forms the heights of Caer Drewgn near Corwen, and a continuation of the same mass separated by alluvium lies west of the town. On the hill it dips easterly under the common Wenlock shale, and there dies out or passes into shale; for south and east of the Llansantffraid fault, though the Tarannon shale is present in a narrow band, no Denbighshire grit lies between it and the Wenlock shale all along the north side of the Lower Silurian boss of the Berwyns.

* 2½ miles south-east of Conway.
† 2 miles south of Llanrwst.
‡ Maps 79 S.W. and 74 N.W.

r Bala.—East of Bala and south of the
the Denbighshire grits form a great
a about 14 miles in length, between the
and the road from Mallwyd to Welsh-
Passing south, it gradually increases
l to 6 miles in width, the plain synclinal
of the north resolving itself into several
ations, in one of which, west of Garth-
the Tarannon shale rises to the surface
anticlinal curve, in consequence of the
al by denudation of the superincum-
grit. On both sides of this trough the
shale and the underlying Bala beds
out to form the Bala country on the one
nd the Berwyn Hills on the other,
manner shown in fig. 97 by Mr. Jukes,
across the country about 6 miles
of the river Dee; but it will be
ed that the Lower Llandovery beds are
ented as thinning away underground on
st, the meaning of this being that the
non shale and Denbighshire grits are
Jpper Silurian strata, and that they lie
formably on the Lower Llandovery and
beds.

th of the Berwyns the plications of the
increase in number and become more
icated; one result of which is, that the
ighshire grits spread over a broad area
en the hills east of Mallwyd and the
bourhood of Llanllugan. In one of
contortions an outlier of the grits has
aved from denudation in the synclinal
of Tarannon, in the manner shown in
am No. 96. The heart of the country
ly, and broken by some noble hills,
generally with a bold western escarp-
overlook the softer Lower Silurian
. From this region the grits stretch far
Radnorshire, and thinning in some degree,
y disappear against a fault near Llan-
n-fawr, north of Builth.

we pass from west to east across any
nuous tract of the Denbighshire grits
they are widest, it appears, as I have
ly mentioned, either that they thin
or are overlapped by the Wenlock shale
country north and south of the Berwyns,
hat seems most probable, the gritty beds
lly pass into true Wenlock shale by
sible lithological gradations. In Den-
hire, on Cyrn-y-brain and the smaller
r Silurian patch south of the vale of
d, Wenlock *shale* lies directly on the
non shales that skirt the Bala beds.
hale along the north side of the Berwyn
, and on the south side, west of Llan-
, where they are much disturbed, they
ally become of less importance, striking eastward, till near Llanfyllin
disappear, and the Wenlock beds have no grits at their base. Neither are
present at the base of the shale anywhere near Welshpool, Montgomery,
ch Stretton in Shropshire, Builth, and the rest of South Wales. I be-
therefore, that they do not deserve to be considered as an independent

Fig. 97.

SECTION ACROSS THE DENBIGHSHIRE GRIT, TARANNON SHALE, AND CARADOC OR BALA BEDS, BETWEEN THE BERWYN HILLS AND THE COUNTRY EAST OF BALA LAKE.

1. Bala beds. | 3. Tarannon shale. | *a.* Bala limestone. | *c.* Ash bed.
2. Lower Llandovery beds. | 4. Denbighshire grits and shales (Wenlock). | *b.* Hirnant limestone.

formation, but are merely a western sandy base of the Wenlock shale, formed during submergence by the denudation of Lower Silurian rocks, many of them felspathic, during the deposition of the Wenlock strata.

In some areas fossils are absent or very scarce in the grits, a few scattered rings of encrinites and ribs of bivalve shells alone showing that they are fossiliferous. At many points, however, fossils are sufficiently plentiful, such as we expect to find in the Wenlock formation.

About 3½ miles south of Conway, about a quarter of a mile east of Merchlyn-mawr, the more common fossils are, numerous fragments of the stems of an *Actinocrinus*, *Stenopora ramulosa*, and *S. fibrosa*; the trilobites are *Phacops Downingiæ* and *Calymena Blumenbachii*; and the more plentiful bivalve shells *Rhynchonella nucula*, *Rh. borealis*, *Strophomena depressa*, *Chonetes lata*, *Orthis elegantula*, and *Atrypa reticularis*.

At Plas Madoc, near Llanrwst, *in addition* to the above we have rings of *Encrinites*, *Cornulites*, and many *Tentaculites*; of trilobites, *Phacops caudatus*, *P. Downingiæ*, *Calymene Blumenbachii*, and *Encrinurus punctatus*; and of bivalve shells *Rhynchonella decemplicata*, *R. nucula*, *Strophomena pecten*, *S. depressa*, *Leptœna transversalis*, *Orthis elegantula*, *Atrypa reticularis*, *Spirifer elevatus*, *S. trapezoidalis*, *Retzia cuneata*, *Cucullella ovata*, *Modiolopsis*, *Ctenodonta*; and of univalves *Acroculia haliotis*, *Holopella gregaria*, *Murchisonia*, *Bellerophon carinatus*, *B. trilobatus*, *B. expansus*; besides an *Otherceras*, and *Phragmoceras nautilium*.

Further east, on the high rocky ridge of Moel Seisiog and Mwdwl Eithen near Pentre Voelas, mixed with many of the species in the above lists, the following additional forms occur: *Favosites alveolaris*, *Stenopora fibrosa*, *Syringopora serpens*, *Glyptocrinus*, *Homalonotus*, and a small species of *Pentamerus*.

North of this ridge, on Craig-hir, near the top of the gritty series, we have *Favosites alveolaris*, various *Encrinites*, including *Actinocrinus pulcher*, the usual Brachiopoda *Cucullella antiqua*, *Cardiola interrupta*, *Euomphalus*, *Loxonema elegans?* *Murchisonia Lloydii*, *Othoceras annulatum*, *O. primævum*, and *O. subundulatum*. In the same grits between the Bala country and the Berwyn Hills the same general list occurs. On and near Caerau Crwyni, south of the river Alwen, and further south on the hills round Pen-y-boncyn, inthe valleys north and west of Llanwddyn, and along the course of the Twrch near Garthbibio, there were found plentifully, *Orthis elegantula*, *Atrypa reticularis*, *Rhynchonella nucula*, *Chonetes lata*, *Spirifer elevatus*, *Stenopora fibrosa*, and fragments of the stems of *Encrinites*. The same general assemblage of species, in fact, appear in varying proportions all the way south to Bedd-Ugre in Radnorshire, and there is therefore no doubt that the grits form a true member of the Wenlock series. What remains to be said of these formations will be best described in the account of the general structure of the Berwyn Hills in the following chapter.

CHAPTER XXVI.

The Berwyn Hills.*

General Description.—The Lower Silurian rocks of the Berwyn Hills form an imperfect dome, or rather an irregular and broken curve, the anticlinal axis of which follows a bent line about 24 miles in length. The eastern end of this dome has been cut away by

* For all of this chapter marked " " I am indebted to my colleague Mr. Jukes, who mapped the Lower Silurian rocks of the Berwyn Hills.

denudation, and is overlapped by the Carboniferous limestone west of Oswestry. From the limestone the axis runs west by Llangadwaladr, Craig-y-Glyn, and Llangynnog, to the base of the Wenlock series, a little north of Garthbibio. Beyond this the anticlinal curve is lost or only faintly traced in the undulations of Denbighshire grit and shale that form the broad hills south of the turnpike road between Mallwyd and Llanfair. The hills in this direction have sometimes been called the South Berwyns, and with the Northern Berwyns they form a watershed running west along the ridge of Mynydd Tarw to Cader Berwyn, from whence further west the watershed is the boundary between Merionethshire and Montgomeryshire, on Craig-wen and Moel-cwm-sarn-llwyd, and then striking southward it crosses Pen-y-boncyn and Moel-y-cerrig-duon to Carrig-y-groes, 4 miles north-east of Mallwyd. All the drainage on the south and east of this line runs into the Bristol Channel by the Valley of the Severn; and all on the north and west, as far south as Moel-y-cerrig-duon, runs into the Dee; while the western drainage south of the same hill flows through the Dyfi into Cardigan Bay.

The general form of the Berwyn range is a curved ridge, convex to the north-west. Passing across the strata from north to south and from west to east the average slope gradually rises, not very steeply, to a height of 2,710 feet on Cader Berwyn, and 2,585 on Cader Fronwen, and these northern "and western slopes are merely furrowed by such brooks as the Trystion, the Llynor, and other small tributaries of the Dee; while towards the south-east the mass is broken into many small hills and ridges, separated by valleys running in many directions." Some of these ridges, above the recess of Llyn-llyn-caws and Cwm-maen-gwynedd, are almost precipitous towards the south and east, a result, taken in connexion with the faulting and older denudations of the strata, probably due to the soft dark blue slaty rocks of that area having been more easily wasted away, after the upper crusts of hard igneous rocks and Denbighshire grits were removed, by those exceedingly ancient marine denudations that planed across and levelled the tops of what are now mountains.

The internal structure of the Berwyn range corresponds to its external form. The position and lie of the beds of which it is composed may be described generally as an irregular oval dome, the side of which is continuous and unbroken on the north-west, but has been crushed in and shattered on the south, while the broken end is concealed on the east by the slightly inclined strata of Carboniferous limestone," already alluded to, "that have been deposited, perhaps quite over the whole mass, and the denuded remains of which, like a great scarped wall, runs north from the Severn across the strike of the Silurian strata."

"We may best learn the nature and succession of the principal masses entering into the structure of the Berwyn Hills by traversing the country between Bala and Llangynnog, especially examining the neighbourhood of the Milltyr Gerrig pass between Pennant and Llandrillo, and then studying the highest parts of

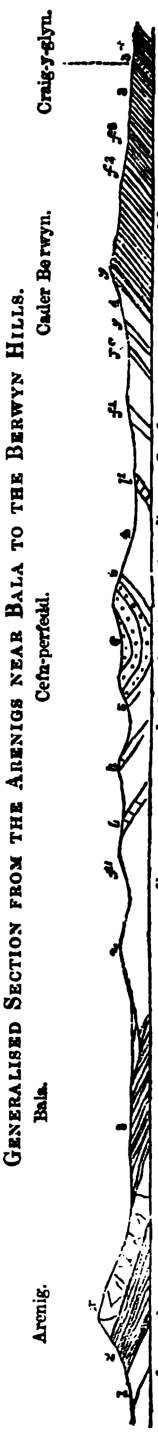
the range and the ridges and valleys leading down from it to Llandrillo on the one hand and to Llanrhaiadr-yn-Mochnant on the other."

The general result of such an examination is, that the Bala limestone and all its associated strata above and below plunge at high angles to the east beneath the Tarannon shale and Denbighshire grits, in the manner shown in Diagram No. 97, p. 211, and rise again with an opposite dip in the region of the Berwyns. Several sheets of sections of the Geological Survey illustrate this point,* which, if generalised and the faults eliminated, would give the result shown in Diagram No. 98.

On the west are the Lingula flags, No. 1, and Lower Llandeilo beds, No. 2, dipping east under the Felstone rocks, *f*, of the Arenigs, which in turn pass below the black shales of the Upper Llandeilo flags, 3. These dip under the Bala beds, 4, including the Upper Bala Ash, f^1, the Bala limestone *l*, and the Hirnant limestone *h*, which are overlaid by the Tarannon shale, 5, and the Denbighshire grits, 6, lying in the form of a trough. On the east side of this trough, and indeed forming the lower part of it, the same Lower Silurian series rises, differing alone in details. The Hirnant limestone, which is very local in the Bala country, is absent in the Berwyns, but the Bala limestone, l^1, is present in force all along the western side of the Berwyn hills. Some distance below the limestone a bed of felspathic ash, f^1, crops out, about 300 feet thick, succeeded in descending order by other beds of similar rocks and of greenstone *g*. These are the representatives, in greater force, of the thin ashy beds below the limestone east and north of Bala lake. East of and below Cader Berwyn the black shaly beds of the Llandeilo flags rise to the surface, the equivalents of those

Fig. 98.

GENERALISED SECTION FROM THE ARENIGS NEAR BALA TO THE BERWYN HILLS.



1. Lingula flags.
2. Lower Llandeilo beds.
3×. Llandeilo limestone.
f. Felspathic lavas and ashes.
3. Upper Llandeilo beds.
4. Bala beds, including f^1, upper Bala ashes; f^2 and f^3, lower ashes; *l* and l^1, Bala Limestone; *h*, Hirnant limestone.
5. Tarannon shale.
6. Denbighshire grits.
g. Greenstone.

* Horizontal Sections, Sheets Nos. 31, 32, 35, 37, 38.

between Bala and Arenig; and the beds of felstone, f^2, low in the series, though probably not identical with that of the Arans and Arenigs, lies apparently much about the same horizon. Seemingly lowest of all, but on ground much broken and faulted, comes the Llandeilo limestone of Craig-y-Glyn,* overlying a bed of calcareous felspathic ashes, which again rest on blue slaty shales. The whole of these are probably the general equivalents of the calcareous ashes and slaty beds that underlie the felstones of Cader Idris, the Arans, and Arenigs, and therefore they lie about the same horizon as the gritty Llandeilo flags, south of the Manods, and of Moelwyn, near Ffestiniog. Nowhere, however, in the Berwyn country, does the section descend so low as the Lingula flags, and therefore the equivalent of the Cambrian strata of Merionethshire and the Longmynd is also absent. Taken in connexion with each other, the three districts of Merionethshire, the Berwyns, and the Longmynd form three great anticlinal curves with synclinal bends between; but in the middle boss of the Berwyns the upward bend has not been sufficient to bring the Lingula flags and Cambrian rocks to a level where they might be exposed by the denudation of the overlying Silurian strata.

It is scarcely needful to remark that the fossils of the district correspond with those of the corresponding strata in the Bala country. Thus, high above the Bala limestone of the Berwyn area on Cefn-grugos, four miles north-west of Llanfyllyn, were found *Cheirurus clavifrons* and *Leptæna tenuicincta*; and on and about the horizon of the limestone west of Llanfyllin, and near Llanwddyn, the following species:—*Stromatopora striatella, Stenopora fibrosa, Tentaculites anglicus, Asaphus Powisii, Trinucleus concentricus, T. seticornis, Phacops apiculatus, Ph. conophthalmus, Calymene Blumenbachii, Beyrichia complicata, Orthis flabellulum, O. Vespertilio, O. elegantula, O. porcata, O. spiriferoides, O. alternata, O. biforata, Strophomena tenuistriata, S. grandis, S. expansa, S. depressa, Leptæna sericea, Atrypa marginalis, Ctenodonta varicosa, Murchisonia simplex,* and *Bellerophon nodosus.* The black slaty shales of the Llandeilo series east of the range of Cader Berwyn and south of Mynydd Tarw, have not been well searched for fossils, but in position and mineral character they resemble those just above and below the felstones of Arenig and Moelwyn, while in the limestone of Graig-y-Glyn itself there occurs plentifully the Llandeilo species, *Asaphus tyrannus,* associated with *Trinucleus concentricus, Orthis turgida, Encrinites,* and *Cystideæ.*

Bala limestone.—I shall now explain the rocks of the Berwyns more in detail, beginning on the west, availing myself for this purpose of the description supplied by Mr. Jukes.

"The thin band of Bala limestone, after plunging to the east in the Bala country, rises again to the surface near the summit of the Llangynnog road, close to the county boundary, just before descending the pass of Milltir-gerrig. In the year 1847 small quarries were to be seen in the limestone, which, with the adjacent slate rocks, dips westerly at angles varying from 30° to 50°.

* Two miles north of Llanrhaiadr-yn-Mochnant.

Igneous rocks, &c.—In the glen under Trwyn-swch, near this, a considerable patch of greenstone may be seen, being almost the only occurrence of igneous rock that I know in this neighbourhood so nearly on the horizon of the Bala limestone. Below this, crossing Craig-wen, and clearly visible on the road side of the Milltir-gerrig, is the band of rock answering to the Upper Bala ash bed. This, however, puts on here rather the character of a compact trap than an ash. It is a pale greenish-grey felstone, but acquires a much more brecciated and ashy character towards the south, while northwards it becomes, perhaps, still more compact and trappean, and increases in thickness.

"Some distance underneath this another band of interstratified igneous rock makes its appearance, not very well seen in the road, but showing well on the tops of the hills at Postgwyn and the grouse box. This is believed to be the Lower Bala ash bed, but, like the former, it is much thicker than in the Bala district, and is seen near the grouse box on Craig-wen to be distinctly interstratified with apparently contemporaneous beds of dark greenstone. These coalesce and become very thick further north on Cefn Penagor, and in Clochnant on the northern side of the ridge sloping from Carnedd-y-ci.

"This ash ends, probably at a fault, to the south in the valley of the Eiarth, but is continuous to the east of Clochnant for many miles, gradually recovering its true form of an ash bed without molten traps.

"A third mass of contemporaneous interstratified rocks comes out from below the two mentioned above on the summit of Carnedd-y-ci. This is a peculiar ash resting on a thick mass of dark greenstone. The ash is quite compact and fine grained, not very hard, of a pale greenish-grey colour, with small dark specks, and is believed to be a greenstone ash,* in contradistinction to a felstone-ash.

"The thicknesses of dark grey slate rock interstratified with all these masses, from the Tarannon shale downwards, is nearly as follows:—From the base of the Tarannon shale to the Bala limestone 3,000 feet, from the limestone to the highest ash bed 1,200 feet, from this to the second ash bed 2,000 feet, and from this to the greenstone ash 1,600 feet, in all 7,800 feet.

"If now we proceeded from the Carnedd-y-ci ash to the summit of Cader Berwyn, we should find that the dark earthy slates which we passed over dipped everywhere to the north-west at 35° or thereabouts, and consequently much more rapidly than the surface of the ground rose to the south-east. We should therefore pass over a considerable thickness of beds, from underneath which there comes out a thin band of greenstone, about 1,600 feet lower in the series, interstratified with, and apparently quite conformable to, the slates, and striking north-east and south-west for about 2 miles.† It is apparently accompanied by a thin ash in part of its course.

"Another similar band of interstratified greenstone comes out lower down, the thickness of slate between the two being about 1,000 feet," giving, when added to the previous 7,800 feet, about 10,400 feet of Bala beds in all. "This lower band, which lies near the top of the Llandeilo series, is seen in the cliffs round Llyn-Llync-caws, and strikes thence north-east and south-west, being traceable for a distance of 3 miles. The dip of the rocks about this lower greenstone however is less than on the other slope of the range, as it varies from 20° down to 50°. If now we follow the brook that runs out of Llyn-Llync-caws, we shall find that the rocks still retain their northerly and westerly inclination till we arrive at the cliffs called Craig-poethion, and here we find another band of trap make its appearance, about 1,700 feet below the last, regularly interstratified with the slates, but of a pale greenish-grey colour and compact texture, being a felstone, like those of Arenig, &c.

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* My former colleague, Professor Oldham, showed me, in London, in the winter after I had surveyed this district, a specimen of a precisely similar rock from Ireland, and asked me if I knew what it was; when I found that he had come to the same conclusion in Ireland that I had in Wales, namely, that this was a greenstone-ash.—J.B.J.

† It is often very difficult, if not impossible, to distinguish between a decomposed trap and an ash. In the case of the felstones, even the finely laminated or flaky structure may sometimes be deceptive, as some of the clinkstones of central France possess this character, and are in other respects very similar to some of the felstone and felstone ashes of North Wales.—J.B.J.

"This trap may be followed over the ridges called Dol Drum and Godor, where other considerable masses of similarly bedded trap may be seen coming out apparently from beneath the slates which underlie the Craig-poethion trap, and 1,200 or 1,500 feet lower than the latter.

"Following the lower trap of Godor back to the Llyn-Llync-caws brook, it may be seen distinctly, opposite the waterfall of Pistyll Rhaiadr, dipping N.N.E. at 30°. Still lower down the brook, and therefore apparently still lower in the series than this trap, are other traps and ashes interstratified very distinctly with the slate rocks, and in some places well shown, but ending so abruptly and so obscurely among bogs and heather that it is impossible to speak with certainty as to their exact position or relations to the surrounding rocks. These are the traps stretching between Tan-y-ffordd and Gwern-feifod, and those running along the cliffs south of Foel-llyn, and traceable north of it towards Rhyd-y-gan.

"It is certain that the trap of Gwern-feifod is very low in the Berwyn series of rocks, and probably not far from the central nucleus of its dome-shaped elevation, and that it is nearly on the parallel of some of the very lowest of the lower trappean masses on the west side of the Arenigs.

"The whole district however is greatly cut up by large faults and dislocations. If we go to the foot of the fine waterfall called Pistyll Rhaiadr, we see an excellent exhibition of a contemporaneous felstone, rudely columnar, interstratified with the slates, and forming the cliff over which the water throws itself. In the adjacent cliffs two other parallel beds of trap may be seen above this, and may be traced across the brook above the waterfall. These three beds, however, seem to end abruptly at faults in each direction, though one of them is apparently continued at a rather different level, as the Craig-mawr trap on the south and that of Craig-poethion on the north. If now we start from the trap above the waterfall and ascend that brook, we find the beds dipping steadily to the west at about 20° till we meet with the lower greenstone (that of Llyn-Llync-caws) at its proper place, or where we should expect to find it, judging from its distance above the Craig-poethion trap. Thus far then all is regular. If, however, after following this bed of greenstone a little way to the summit of Bryn-mawr, we proceed still further west, scarcely half a mile, to Post-gwyn, we should come upon the Lower Bala ash bed, the rocks in the intermediate space being seen to dip at no greater angle than 25°. But this Lower Bala ash bed is traceable to Clochnant, 3½ miles to the northward, and if from Clochnant we attempted to walk back to the nearest point of the Llyn-Llync-caws greenstone, we should have to pass over 2½ miles of ground (as measured on a map) instead of half a mile, with the intermediate rocks dipping steadily to the north-west at angles of 20°, 35°, and 40°, instead of only 25°, and containing the Carnedd-y-ci ash and greenstone, the Cader Berwyn greenstone, and the thick intermediate slate bands between them. Of all these beds there is no trace, as indeed there is no room for them, between Bryn-mawr and Post-gwyn.

"The thickness of rock between Bryn-mawr and Post-gwyn, calculated from the data there seen, would be about 1,100 feet, while that between Llyn-Llync-caws and Clochnant would be between 6,000 and 7,000 feet. The difference between these two figures (say 5,000 feet) would represent the thickness of beds wanting, that is, concealed by a fault, between Bryn-mawr and Post-gwyn.

"If we take it as proved that some large dislocation exists, and suppose it to run about N.N.W. and S.S.E., it will touch and account for the abrupt westerly termination of the Carnedd-y-ci ash on the north, and for the equally abrupt endings of other beds of ash, trap, and slate for several miles to the north.

"Now it is a good maxim to be as chary as possible in introducing a fault into any district, to avoid supposing the existence of one until it is either demonstrated or rendered so highly probable as to be hypothetically necessary. When, however, one large fault is thus proved, the existence of others almost follows as a matter of course, since it is scarcely possible, physically, for a single large fracture to traverse a mass of rocks and produce great dislocation, unaccompanied by others neighbouring to it and connected with it.

"If, then, we hold it allowable to account for the abrupt termination of the beds above mentioned on one side by means of a fault, it is equally allowable, and indeed necessary, to draw a fault along the other ends of these beds; that

is to say, along the ends of the Carnedd-y-ci ash, the greenstones of Cader Berwyn and Llyn-Llync-caws, and the traps of Godor, and the slate beds with which these are interstratified. All these beds end abruptly along the southern bank of the valley of the Iwrch; while to the north of that valley all the rocks of the ridges of Y Foel-wen, Mynydd Tarw, and the country around Llanarmon Dyffryn Ceiriog, appear to be composed of the black slates which lie above the Cader Berwyn greenstone, variously crumpled and rolling about. Between these two main lines of fault, running nearly parallel north-west and south-east, but slightly diverging in the latter direction, there appears to be another parallel to them running down the valley of the Rhaiadr from the neighbourhood of the waterfall, and many other minor dislocations crossing and connecting these in various directions.

"The traps of Craig Rhiwarth, just north of Llangynnog, are felstones, in some places distinctly interstratified with the beds of slate, while in others they form great shapeless masses, ending abruptly and without showing their relations to the surrounding rocks. The lead lodes for which the district was celebrated run nearly east and west, and form a portion of the dislocations by which it is traversed, many other faults being traceable by means of the sudden termination and broken endings of the different masses of rock of which the country is composed.

"The hill of Y Garn, east of Craig Rhiwarth, is similarly composed of trap and slate, which may be seen in places distinctly interstratified, while their relations in others are obscure and their boundaries uncertain.

"On the opposite side of the valley of the Tanad is a mass of hills, part of which is called Cymia. Along the southern side of these hills the slates are regularly interstratified with felstone ashes or traps. These beds are very regular, dipping south at a high angle about Peniarth, at the eastern end of the hill, and are equally regular in many places all the way along by Craig-ddu to its western extremity. There are, however, places about Craig-ddu where the position of the beds is so discordant to the rest, and the change of dip and strike so frequent, sudden, and irregular, that it was found to be impossible, with the small scale of the one-inch map, to disentangle the confusion. Many large faults must exist, one at least of which contains lead ore, and is, or was, worked with profit.

"The eastern extremity of these beds is supposed to be cut off by the main fault first described, coming down from Bryn-mawr, and this appears to run still further south through the ridge of Dâs Eithin, where it was found formerly to contain lead ore. At this extremity of its course, however, the beds are vertical, or nearly so, and therefore no lateral shift is produced by it at the surface."

Limestone.—"Let us return now to the band of Bala limestone, with which we commenced our description, on the road above the Milltir-Gerrig pass. This little band of limestone, with the larger and more prominent ash bed about 1,000 feet below it, are traceable southwards at short intervals, wherever the rocks appear from under the peat, heather, or soil with which they are covered, down into the pretty little valley of Pennant, and thence for four miles, across wild moors and hills, to the larger and more open valley of Llanwddyn. They are here thrown into the form of a sharp and distinct anticlinal curve, the axis of which runs about N.N.E. and S.S.W., sloping or declining towards the south. One side of the point or 'nose' of the ash bed just comes across the river Fyrnwy, being seen under the farm-house called Bryn-du, about 2 miles below the village of Llanwddyn. From the other side of the river the two ribs of ash run continuously northwards, but gradually diverging from each other as the anticlinal spreads owing to the rise of its axis. The beds on the west side dip to the west at angles of about 20° or 30°, while those on the other slope dip east and south-east at angles of 75° and 80°, increasing up to 90°, and eventually being inverted to the amount of 10° beyond the perpendicular, and dipping north-west, or toward the axis, at 80°," and this reversed dip of the Bala beds, both below and above the limestone, of the Denbighshire grit and the overlying Wenlock shale continues on a north-east strike for a distance of about ten miles, all the way from the neighbourhood of Garthbibio (Map 60 N.W.) to the country two miles south of Llanrhaiadr-yn-Mochnant (Map 74 S.E.)

"The southern termination of the limestone at the surface, as it crosses over

the anticlinal ridge, may be seen in the little valley of the Cowny river, about 3 miles south of Llanwddyn (Sheet 60 N.W.) A little above Pont-y-Llwynog a thin band of dark limestone and calcareous slate may be traced across the brook, dipping S. 10° W. at 35° on the south side of the river, where it suddenly ends, and curving round higher up till it dips west at 30°, and then strikes off north of Llanwddyn.

"In the other direction its continuation was found to be thrown by a fault nearly a quarter of a mile to the south, being found just south of a farm-house called Ffrith-Cowny, dipping south at 60°; from which place it strikes off north-east, and is seen again in rather a debased form at about a mile distance just east of Ty-newydd. It here dips N. 30° W. at 75°, being affected, along with all this band of country, by the inversion of dip mentioned before.

"The limestone then assumes the form of a calcareous sandstone rather than of a true limestone, but may be traced at intervals, accompanied by phosphatic matter close on the S.E.,* running in a straight line north-east for 6 miles to Wern-y-scadog, and the road between Llanfyllin and Llangynnog. For the details of the structure of this district I must refer to the maps (Sheet 74 S.W. and 60 N.W.), but would add that the interest to be derived from the study of a locality in which so many and such various physical features are so admirably shown, is heightened by the fact of the limestone and parts of the ash beds and all the beds about them being crowded with a vast variety of fossils, containing, I believe, all the characteristic species of the formation, and generally in a well preserved condition.

"From this corner of the Berwyn district, where the rocks are pinched up into an anticlinal, forming, as it were, a tail to the dome-like elevation, the upper beds open out towards the north-east, and allow of the appearance from beneath them of the lower beds about Llangynnog. It is remarkable, however, that on the south-east side the ash dies out very soon, simultaneously indeed with the change of the beds about it into a sandstone, and the limestone itself becoming arenaceous.

"If we follow these rocks eastward towards Llanfyllin, the whole of the Bala beds are found to acquire a strong arenaceous character, and to resemble the Caradoc sandstone of Shropshire rather than the beds about Bala. So strongly were Mr. Aveline and myself impressed with this, that we sent a box of specimens to Professor Forbes to know if they were not Caradoc fossils. He replied that they were all Bala species, but this prepared me to receive the statement that the Bala and Caradoc rocks were the same.

"The rocks around Llanfyllin generally strike east and west, but are thrown into such a number of rapid folds and convolutions that it is impossible to follow any one bed or to trace any one horizon through them, seen, as they are, only in detached quarries or small natural sections.

"I have sometimes thought it possible that the ash beds of Craig-ddu and these hills south of Llangynnog might be the Bala ash repeated by sharp folds and dislocations.

"The ridge of Craig-y-gorllwyn, again, 2 miles east of Llanrhaiadr-yn-Mochnant, contains a strong thick well-marked ash bed running unbroken nearly 2 miles, and so like one of the Bala ash beds that we were strongly tempted to consider them equivalents.

"It dips S.S.E. at 45°, and therefore it plunges under all the fossiliferous sandstone country south of the Tanad in which the Bala limestone ought to lie, but its relations to the limestone of Craig-y-glyn is uncertain.

"Between the Craig-ddu ridge (south of Llangynnog) and that of Craig-y-gorllwyn there is a gap in which neither limestone nor ash has been found near their regular strike, but 2 miles north-west of this strike, in the valleys of the Rhaiadr and Iwrch, detached fragments half a mile or more in length of a limestone, resting on a bed of gritty ash, not very unlike the Bala limestone, make their appearance. They gave me at the time the notion of their being detached portions of the Bala limestone thrust bodily thus far from their original place by the action of the great central dislocations mentioned before,

* This phosphatic matter was not observed when the country was surveyed, but it has lately been discovered, and promises to be of much value, containing in some cases, according to Dr. Voelcker, from 48 to 64 feet of phosphate of lime.

and let down as it were into the heart of the lowest rocks of the central mass of the dome-like elevation.

"One of these masses of limestone may be seen at Gorwyllt, on the south side of the valley about 2 miles above Llanrhaiadr-yn-Mochnant. It dips S.S.E. at 85°, resting on a gritty ash bed ending one way in the Rhaiadr, and in the other direction in a brook against some black slate which dips N.W. at 10°.

"The other and more considerable patch of limestone is at Craig-y-Glyn, a little more than a mile north of Llanrhaiadr, where the limestone likewise rests on a bed of ash, and these two pieces of limestone are doubtless part of the same bed.

"It appears, however, from the fossils it contains that the Craig-y-Glyn limestone is not the Bala but the Llandeilo limestone, and that it must, if anything, be brought up by the faults from below rather than be let *down* from above.

"Leaving now this dislocated centre, and again returning to the point where we commenced, on the road above Milltir-gerrig, let us follow the upper beds to the north and east. In doing this we shall have as much reason to be struck with their steadiness and regularity as we have just had with the confusion of the central district.

"From the summit of the ridge called Craig Wen and Pen-y-bryniau the whole of the beds strike regularly north, dipping west at angles varying from 20° to 35°, in the manner shown in fig. 98, and in a more generalised form for all the strata of the district in fig. 99.

"These as they approach Llandrillo curve gently and steadily round towards the east till they strike due east and dip north at angles of 15° and 20°. This east and west strike is steady for a distance of 8 miles to the valley of the Ceiriog between Llanarmon-Dyffryn-Ceiriog and Llansaintfraid-glyn-Ceiriog, beyond which it curves a little to the south, and the beds strike E.S.E. towards Selattyn, till they are covered and concealed by the Mountain limestone and Millstone grit, which run north and south right across them. The Bala limestone indeed is not at all continuous, or, if so, is not visible throughout the whole of this sweep. Calcareous and concretionary beds that doubtless represent it may be seen a little above the road between Craigiau-duon and Blaen-dinam, about 1½ miles S.S.W. of Llandrillo. Similar calcareous bands may also be seen about 2 miles east of Llandrillo, in the gullies of Nant Brian and Nant Gwynn, just south of their junction.

"With these exceptions, nothing was to be seen of the limestone till we reached the Ceiriog, south of Llansantfraid, though the fossils were found abundantly at intervals in all the beds near its margin.

"Just south of Llansantfraid Glyn Ceiriog, two bands of limestone make their appearance, of which the lower one is doubtless the true representative of the Bala limestone. They are well seen, having been quarried and burnt for lime, and, together with the beds of slate in which they lie, are full of the Bala fossils.

"It would appear from the position of these beds, with respect to the Upper Silurian beds north of them, that the Upper must be unconformable to the Lower Silurian formation."

Ash Beds.—"The Upper Bala ash bed, so well shown in the anticlinal east of Llanwddyn (Sheet 74 S.W.), and so clearly traceable from it to the northwards by Moel-di-Moel, Craig-y-castell, the crags over Blaen Rhiwarth, assumes thence, as has been before stated, the character of a trap rather than an ash. From Craig Wen to Tyn-y-nant it is a smooth compact felstone, with small dispersed crystals of felspar. About a mile south of Llandrillo another thin band of ash may be seen coming in over it, and this, which we called the Little ash, is traceable thence for 8 or 10 miles to the eastward. After passing over Trum-y-wern, the Upper Bala ash reassumes its normal ashy character, and together with the Little ash bed forms conspicuous crags in all the gullies and ravines, and often as conspicuous ridges along all the escarpments which it traverses, from Pont-rhyd-y-rhyd to the Ceiriog, south of Llansantfraid, and the escarpment of the Carboniferous limestone.

"The Lower Bala ash bed is well seen on Post-gwyn, where it consists of greenstone ash at top, with coarse ash below, and a bed of greenstone under

that. At the Grouse Box, on the ridge to the north of Post-gwyn, a thickness of about 200 feet of alternations of two beds of greenstone with greenstone-ash may be seen; and further north the two beds of greenstone coalesce into one strong bed, which runs thence regularly round into Clochnant, and after crossing the ridge called Trawsnant, gradually thins out and dies away south of Hafodty-llynn. The ash over this greenstone is of that peculiar fine-grained smooth texture and greenish-grey colour with dark specks that is characteristic of greenstone, and it retains that character for some distance to the eastward of the watershed as far as the valley of Nant Rhyd-wilym. It gradually gets coarser to the east, however, and assumes the form of a coarse flaky ash like the Upper ash, which it follows persistently and with similar features across the country by Craig-fawr, and Moel-ewig, and Pen Llyn-gloyw, to the picturesque little valley of the Ceiriog so often spoken of before.

"From this point it is still distinctly traceable by the cliffs south of Gwastad-mawr to Llechrhydau and the woods of Cefn-coch, where in some places it is associated with beds of felstone containing crystals of pink and green felspar. It seems to be getting thicker too and more important, but at 'The Springs' is finally covered by the Mountain limestone.

"Parallel to these long continuous bands of ash, and from 500 to 1,000 feet beneath them, is a little bed of greenstone, lying in the plane of the slate beds, and nowhere producing any great alteration nor any disturbance. It is about 20 or 30 feet thick, and stretches from Cwm Llawenog, through Mynydd Bach, north of Llanarmon, to Pen-y-gwely, a distance of 7 miles. It appears to die out in each direction, and may be either a representative of the Carnedd-y-ci or Cader Berwyn greenstones, more probably the former.

"From beneath this again came out the dark slates and gritstones of the Llandeilo flags, making the ridges of which Mynydd Tarw is the chief, the beds still dipping generally to the north at angles of 30° or thereabouts, and striking to the east, in which direction they pass into some singular black sandstones about Craig-yr-hwch, Bwlch-y-domgay, and Allt-y-gwrach.

"Perhaps still lower beds may come out in Mynydd Mawr and Gyrn Moelfre, but this is very doubtful; and the absence of any appearance of trap of any kind between Llanarmon-Dyffryn-Ceiriog and Llanarmon-Mynydd-mawr, Llangadwaladr and Llansilin, makes it probable that this district is occupied by the black slates lying above the traps, those forming the western slope of Cader Berwyn or the neighbourhood of Llyn Llync-caws.

"Traps and ashes, however, make their appearance in considerable force in the south-east corner of the district, coming out from under the Carboniferous limestone in four irregular patches at Pwllau-meirch, Tre-arglwydd, Ffynnon-dêg, and Blodwel Hall. These in some places consist of felstones or greenstones of a massive character, in others of regularly bedded ashes, sometimes interstratified with the slates. Some of these contain crystals of pink felspar, and otherwise resemble the Lower ash bed as it appears a few miles to the northward at Llechrhydaw and Cefn-coch; and it is probable that a considerable mass of igneous rocks belonging to the Silurian formation may be concealed under the Carboniferous beds to the east, with which the Lower ash bed was conncected."

Summary.—The result of the foregoing description is, as already stated, that in the Berwyn hills there is a repetition of the rocks of Bala and the country to the west as low as the Llandeilo beds, but that in the Berwyns the Lingula flags and the Cambrian strata are absent. Of the interbedded igneous rocks, the two highest beds represent the ash beds of Bala and the great contemporaneous felstone and ashy beds of Dolwyddelan and Snowdon. Probably, indeed, they are precise equivalents. The lower bedded greenstones and felstones are the general representatives of the great semicircular group of igneous rocks that range from Cader Idris by the Arans, Arenigs, Manods, and Moelwyn, to the neighbourhood of Tremadoc. But in the

Berwyn country they are much thinner and less varied than in Merionethshire. The total thickness of the strata is as follows:—

		feet.
Bala beds above the limestone, about	-	3,300
„ below „ „	about 4,500 to	4,800
Llandeilo flags, about	- - - -	4,500

making 12,300 feet of Lower Silurian strata, exclusive of the Lingula flags.

CHAPTER XXVII.

Upper Silurian Shales and Flagstones of Denbighshire and Flintshire, Old Red Sandstone, Carboniferous Limestone, and New Red Sandstone.

Boundaries of the Upper Silurian Rocks, and Carboniferous Limestone.

General Description.—I have already mentioned the lower boundary of the Wenlock shale where it overlies the grits of Denbighshire, from the mouth of the Conwy to the country near Corwen, and from thence along the northern flanks of the Berwyn Hills. It now remains briefly to notice its upper boundary and the interior country formed of Upper Silurian rocks in Denbighshire. On the right bank of the estuary of the Conwy, opposite the town, they are bounded on the north by the Carboniferous limestone, which there, on the heights of Gwylfryn and Bryn Curian, dips northerly and forms a bold escarpment that overlooks the hollow of Llangwystenin, striking out to sea on the north-west side of Rhos bay. Curving round (probably immediately beyond the shore), the limestone again touches the coast near Colwyn, and its base strikes for about two miles to the south-east as far as Tyn-y-pistyll, near which, south of Llysfaen, a band of Old Red Sandstone marl and cornstones crops out, and resting on the Wenlock shale, strikes eastward (interrupted by a small fault) as far as the neighbourhood of Twll-llwynog, at the opening of the valley that passes down to Abergele. Across this valley the limestone seems to rest directly on the Silurian strata, but the ground is much obscured by drift. On the opposite side, close to Plas-uchaf, the Old Red Sandstone again emerges, and reposing on the Wenlock shale shows itself for about a mile and a half in a narrow strip to the neighbourhood of Dinorben, when it is again overlapped by the Carboniferous limestone, which then ranges two miles south-east to a point above the river Elwy, at a bend in the road from Pen-y-bont to Croes-ffordd or the Crossways. Here the Old Red Sandstone again crops out and separates the Wenlock shale from the limestone in a narrow strip of about seven

miles in length, which stretches by Henllan to the road a quarter of a mile south of Denbigh, where it is again overlapped by the Carboniferous limestone. The grounds of Segrwyd lie on a small outlier of this limestone, which above the river on the north rests on the Old Red Sandstone, on the N.W. is faulted against the Wenlock shale, and on the south and east lies directly on that formation. Near Denbigh the New Red Sandstone, though deeply concealed by drift, seems to cover up the limestone, and to intrude itself upon the Wenlock shale for about a mile, when the Carboniferous rocks again crop out a mile and a quarter west of Llanrhaiadr and cover a space of something over a mile square, resting highly unconformably on the Wenlock shale. South of the brook at Pandy the New Red Sandstone again intrudes itself on the Wenlock rocks for a mile, but near Ty-mawr the limestone and Old Red Sandstone again appear, the latter in a narrow line skirting the Wenlock shale as far as the branch in the turnpike road immediately west of Llanfwrog, near Ruthin. Throughout all this tract, from the neighbourhood of Colwyn by the sea to that near Ruthin, these narrow strips of red rocks seem to form part of the same set of strata as the Old Red Sandstone of Anglesey, and both apparently belong to that upper part of the formation which is intimately related to the Carboniferous limestone series.

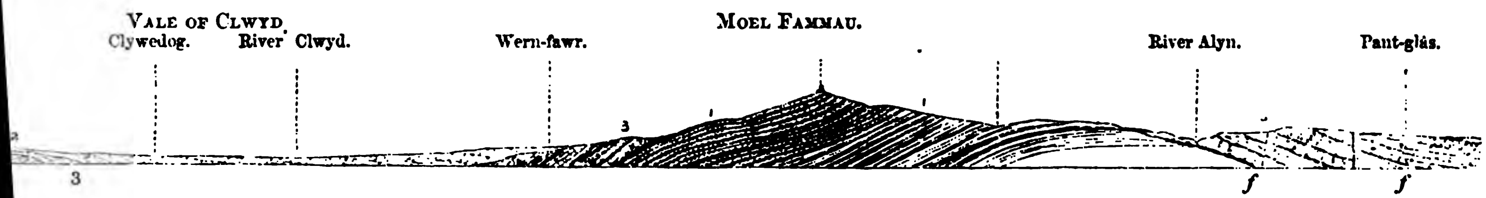
South of Ruthin the Old Red Sandstone disappears in Denbighshire, and the bold Carboniferous limestone escarpment of Coed Marchan and Craig-y-adwywynt rests directly on the Wenlock shale and dips east at angles varying from 10° to 20°. At its south end, about half a mile east of Llanelidan, it is thrown down against the shale by an east and west branch of the great Bala fault, which being a downthrow on the north, throws the limestone against the Wenlock shale and the shale against the Bala beds on the north side of Cricor-mawr.* The limestone, about 1,000 feet in thickness where exposed, dips at an angle of about 40° to the north, resting quite unconformably on the Wenlock shale. This unconformity takes place all along the line above described, from the mouth of the Conwy to the neighbourhood of Llanelidan, south of the Vale of Clwyd, a distance of about 30 miles. Wenlock shale, Old Red Sandstone, and Carboniferous limestone all dip, as a whole, to the north-east; but whereas the dips of the the Old Red beds and of the limestone are steady in their direction, and dip at angles of from 8° to 20° and 25°, the Wenlock strata lie at all inclinations up to 65°, and frequently the beds strike towards the limestone or dip away from it close upon the points of junction.

On the eastern side of the valley the Carboniferous limestone in the low ground rises here and there in a few narrow strips from underneath the shroud of New Red Sandstone that fills the bottom of the Vale of Clwyd. From the point where the limestone curves round on the south, it first strikes north about a

* Six-inch Sections, sheet 38, line 6.

Fig. 99.

TION ACROSS THE UPPER SILURIAN ROCKS, OLD RED SANDSTONE, CARBONIFEROUS LIMESTONE, MILLSTONE GRIT, PERMIAN ROCKS, AND NEW RED SANDSTONE, OF THE VALE OF CLWYD AND ITS NEIGHBOURHOOD.



1. Upper Silurian rocks (Wenlock).
2. Old Red Sandstone.
3. Carboniferous limestone.
4. Millstone grit.
5. Permian rocks.
6. New Red Sandstone.

iarter of a mile in width for three miles, along the east side of ie valley, in the ridge of Y-Graig-wyllt. It is then covered up r the New Red Sandstone, but again shows itself in a little itch east of Llanrhydd. A second occurs south-east of Llan-edr, and a third for more than a mile S.S.E. of Llangynhafal. ig. 99, No. 3, W. of Moel Fammau. A fourth, a mile and a alf in length, lies east and south-east of Llangwyfen. At Wern is overlapped by the New Red Sandstone, but again crops out r a short space at Bodfari. Beyond this it rises on the hills amediately north and south of Tremeirchion, but is again overed up by the New Red Sandstone near Tyddyn-domarch, id from thence to Pentre-bach near Diserth, at the mouth of ie Vale of Clwyd.

I have lately been informed by Mr. Maw, of Benthall Hall, iat he has observed three small Permian patches of red marles nd sandstones between the limestone and the New Red Sand-tone, one at Pentre Methiant near Llanfair Chapel, another south f Llangynhafal, and the third at Llangwyfen.*

Along all this range of about 20 miles in length the limestone nd overlying New Red Sandstone dip westward, the sandstone, 'here visible, at a low inclination, and the limestone at angles arying from 10° to 20°. The Wenlock shale rises quite uncon-ormably from beneath them, forming the fine range of lofty hills iat stretches from the valley of Bryn-Eglwys on the south to 'wm, east of Rhyddlan. The loftiest hill in this range is Moel 'ammau, which rises more than 1,800 feet above the level of the ea.

The range of Moel Fammau.—Between Pentre-bach, near Disserth, and the neighbourhood of Tommen-y-Rhodion, near Llandegla,† the Carboniferous limestone bounds the Wenlock hale of the Moel Fammau range on the east. The line forms a reat irregular curve about 22 miles in length, passing from Moel-iraddug on the north to the country a mile west of Caerwys, hen S.E. along the slopes on the north side of Afon Chwiler and y Cilcen and Llanarmon to a sudden bend in the Ruthin road, vhere, near Penant-isaf, it is thrown down against the Wenlock hale by a branch of the Bala fault. Here and there the con-inuity of its base line is broken by small faults, some of which, etween Cilcen and Llanarmon, are lead veins, which lose their 'alue as they pass from the limestone into the Wenlock shale. As a whole, the limestone, in long terraced lines, dips east at omparatively low angles (15° to 20°), forming long gentle slopes, vhile the western escarpments form comparatively steeply loping hills. The Wenlock shale, on which it rests quite uncon-ormably, rises from underneath with a high and irregular yet weeping outline. The sides of the long range are scarred by many valleys, and altogether it forms a marked contrast in its

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* When this area was mapped, the Permian rocks of the middle of England had not been clearly separated from the New Red Sandstone. A precise separation was first made by the Geological Survey.

† About 10 miles in a straight line west of Wrexham.

heights to the tamer slopes of the Carboniferous rocks below. No. 1, Fig. 99, Moel Fammau.

Though the Upper Silurian rocks are occasionally somewhat contorted, the prevalent dips are to the westward at all angles, ranging up as high as 70°, so that the outcrop of the lowest beds of Carboniferous limestone on the east side of the range probably lies almost on the base of the Wenlock shale.

Llangollen.—South-east of the Vale of Clwyd, between the Bala beds of Cyrn-y-brain and the Berwyns, the Wenlock shale fills a space about 6 miles broad, consisting of steep-sided round-topped hills, intersected from east to west by the river Dee. Numerous subsidiary valleys branch north and south from the river into the heart of the hills. On the east, between Craig Arthur and Ty-uchaf,* the Old Red Sandstone rests unconformably upon it. From thence to Tan-y-Castell† a fault passes from Y-fron-fawr to the south-east, and throws first the Old Red Sandstone and then the Carboniferous limestone and millstone grit against the Wenlock shale above the river Dee to a point 4 miles east of Llangollen.

West of the Vale of Clwyd.—The Upper Silurian rocks that lie west of the Vale of Clwyd present in part the same kind of physical features that mark the rocks on either side of the Vale of Llangollen. A wide tract of high hills strikes westward from the upper part of the valley towards Llanrwst. The rocks dipping northerly, these hills are apt to be scarped towards the south, and their height is partly due to resistance to waste, because of the hardness of the Denbighshire flagstones and grits that here form the base of the Wenlock strata.

The chief drainage of this country flows northward through a perfect network of valleys, and gradually uniting to form larger streams, the water at length finds its way into the river Clwyd through various gaps in the limestone rocks that flank the Wenlock shale on the east. I know of no better area in Wales than this part of Denbighshire by which to prove the effects of running water in cutting out in an old table-land that labyrinth of valleys, sometimes shallow, sometimes deep and steep-sided, the accumulated waters of which have in places cut their way from high to low levels across the escarpment of Carboniferous limestone that flanks the Wenlock shale on the east. The whole country in fact is intersected by valleys so numerous and comparatively so steep on the sides that there is scarcely any part of Wales more difficult of access than this part of Denbighshire. It is essentially a rural district, without large rivers, without mines or centres of trade, and even without villages or market towns of any importance, in an area of about 25 miles in length and from 6 to 14 in width. The very roads convenient for driving are few, and in general you may walk faster in the heart of Denbighshire than you can ride.

A long band of sandstone lies in the heart of the country, but the rest of this part of Denbighshire is shaley and flaggy,

* About 2 miles north of Llangollen. † 1 mile north of Llangollen.

with a tendency to become sandy in the higher strata, some of which may belong to the Ludlow rocks. The scarcity of fossils, however, and the absence of dividing limestones, renders this uncertain, and yet near Corwen the shaley and concretionary character of about 1,700 feet of rocks at the base, and further east and north the flaggy and sometimes sandy nature of about 3,000 feet of higher strata, agrees tolerably well with somewhat similar developments in Shropshire and South Wales.*

In Denbighshire, fossils have mostly been found in the lower part of the series in dark blue or blackish shale. They chiefly consist of thin-shelled *Orthoceratites, Orthoceras primævum, and O. ventricosum,* with *Cardiola interrupta,* a few *graptolites* (*priodon*), and *Encrinites* (*Actinocrinus pulcher*), sometimes in rings and fragments and sometimes with the heads attached to long stems.

General physical structure of the Vale of Clwyd and its neighbourhood.—The physical structure of the Vale of Clwyd and the hills on either side will be understood by reference to Fig. 99, and may be briefly summed up as follows:—

The whole consists of a long synclinal curve, with minor undulations, partly formed of Upper Silurian rocks. The eastern side of the bend, as far as Upper Silurian rocks are concerned, consists of the Moel Fammau range, and the western boundary stretches from Conway to Derwen, from whence the whole synclinal basin runs in a narrow strip far south to Tarannon in Montgomeryshire. Much denudation had taken place long before the deposition of the Carboniferous limestone, and in a denuded synclinal hollow the limestone was deposited that now underlies the Vale of Clwyd, and an outlying fragment of which occurs near Corwen, on the Dee. Long after, other elevations, with lower angles, repeated the synclinal curve in the limestone of the valley, and denudations took place. Before the deposition of the New Red Sandstone, gaps had probably been cut in an escarpment of Carboniferous limestone, as for instance between Denbigh and Llanrhiadr, also south of Llanrhiadr, and again at Llanfwrog, near Ruthin; and it is likely that these denudations had already removed from this area Coal-measures that once covered the limestone before the deposition of the New Red Sandstone commenced. In the hollow of the limestone thus formed the lower beds of the New Red Sandstone stretch from end to end of the beautiful Vale of Clwyd, which at its mouth near Rhyddlan is about 6 miles wide, and trending S.S.E. for more than 20 miles it gradually tapers to about a mile in width, near Llanfair, south of Ruthin. Seen from the heights above Bryn Eglwys,† there are few scenes in Wales more lovely than the wooded plains of the Clwyd. Overlooked on one side by the barren range of Moel Fammau, and on the other by the limestone cliffs of Denbigh and Abergele,

* Through Radnorshire to Builth, over a large area, the Wenlock shales are about 1,500 feet thick, and often full of calcareous concretions, while from 2,000 to 3,000 feet of sandy strata lie between them and the Old Red Sandstone.

† About 6 miles south of Ruthin.

the fertile lowland forms a marked contrast to the wildness of the hills amid which it lies, while far in the distance the plain merges at length into the low alluvial marshes that skirt the shores of Rhyl. There is no other part of Britain where the secondary rocks lie so enclosed, as if in a great bay, in the heart of the Palæozoic formations; and it is this that gives a charm so peculiar to the scenery of this remarkable depression. The structure of the whole valley is typified in the section, Fig. 99, which crosses the country a few degrees north of east over Moel Fammau.

Though foreign to the subject of this memoir, it may here be advisable to give a little additional matter about the New Red Sandstone of the Vale of Clwyd, especially as persons occasionally speculate as to the probable occurrence of coal in the valley underneath that formation.

The valley in general is so deeply covered by drift that the New Red Sandstone is rarely seen in place; but it is probable that it entirely belongs to that lowest member of the Bunter Sandstone which in Cheshire and the central counties has been mapped by the Survey under the name of the Lower Soft Red or Variegated Sandstone. It is probable that in parts of the valley within the edges of the New Red Sandstone the Permian strata lie between it and the Carboniferous formations; but it is worthy of remark that on the east of the Denbighshire coal-field the Permian beds do not extend northward more than a mile beyond Gresford, and this taken in connexion with the occasional narrow strips in which it is said to appear at the base of the New Red Sandstone helps to indicate that it may not generally underlie that formation throughout. Neither is it to be supposed that productive Coal-measures probably lie in the Vale of Clwyd. On the contrary, it seems not improbable that south-east of Rhydd-lan, between Disserth and Tremierchion, the Carboniferous limestone and Permian rocks lie close inside the edge of the New Red Sandstone, and that the whole of the rest of the last-named formation is underlaid chiefly by the limestone, except in occasional spots where it rests on Wenlock shale. If this be correct, then on the north the limestone of Disserth curves round beneath the New Red Sandstone and alluvium of Rhyddlan, and striking west with a northerly dip passes seaward beneath the marsh at Abergele, throwing any possible productive Coal-measure out to sea underneath Rhyl flats towards Constable Bank.

CHAPTER XXVIII.

SUMMARY.—DISTURBANCE AND DENUDATION.

The chief object of this Memoir has now been accomplished, for I have described in detail the Cambrian and Lower Silurian rocks of Merionethshire, Caernarvonshire, and Anglesey, and in a briefer manner the Upper Silurian and other strata that lie strictly within the region I proposed to illustrate. I shall now, in conclusion, revert to some leading stratigraphical and palæontological points, by way of summary, and also partly to show the general connexion of the region described with other parts of Wales, in such a way as to explain the effect of the whole on its physical geography.

First, then, the term Cambrian has been applied by the Geological Survey only to those strata that lie directly below the Lingula flags, and which, excepting worm-burrows, have heretofore only yielded doubtful fossils. These are the oldest strata in Wales, and are believed to be the equivalents of the Irish rocks at Bray, and of the red conglomerates and sandstones in the north-west of Scotland described by Sir Roderick Murchison. In Wales, however, we never get to their base, and whether or not they lie unconformably on gneiss, like that of the Lewes and the St. Lawrence, it is vain to speculate.

The relation, however, of the Cambrian to the overlying strata is clear, for everywhere in Wales there seems to be conformity, and even a gradual passage from the Cambrian rocks to the Lingula flags. They are, therefore, intimately related to each other, and perhaps, except for the convenience of a great lithological distinction, they scarcely require separation by line and colour.

The Lingula flags, from 5,000 to 6,000 feet thick where thickest, contain, as at present known, about 22 species of Trilobites of the genera *Dikelocephalus* (4), *Agnostus* (5), *Olenus* (7), *Conocoryphe* (*Conocephalus*) (3), *Ellipsocephalus* (1), and *Paradoxides* (2); *Hymenocaris vermicauda*, and 3 Brachiopoda (2 *Lingulæ* and an *Orthis*), 1 Polyzoon (Dictyonema), and several Annelids.

Above the true Lingula flags lie the Tremadoc slates; and Mr. Salter first proved that the fossils of these beds are mainly distinct from those of the Lingula flags below and of the Llandeilo and Bala beds above them. Thus of 11 genera of Tribolites only Dikelocephalus, Conocoryphe, Olenus, and Agnostus, are common to the Lingula flags, and the species are entirely distinct. The remaining seven are *Angelina, Asaphus, Cheirurus, Ogygia, Ampyx, Psilocephalus,* and *Niobe.* The Pteropod *Theca*, and *Bellerophon*, *Conularia*, *Orthoceras*, and *Cyrtoceras*, as far as we know, first appear in the Tremadoc slates in Britain. Of the Tribolites, *Agnostus princeps* seems to be the only species common to Lingula flags and Tremadoc slate, and of a tolerably numerous list of bivalve shells *Lingulella Davisii* and *L. lepis* are the only forms that ascend from the lower horizon. It

was not till after the whole of Wales had been mapped that the existence of the Tremadoc slate as a recognizable subformation was suspected, for where almost all the rocks are slaty, and where there is no visible break in conformity, minor lithological distinctions are generally of small value. All known evidence, however, tends to prove that in Wales the Tremadoc slate is a very local formation, and though searched for, none of its peculiar fossils have yet been found in Wales, except in certain spots in Merionethshire and Caernarvonshire.

Next come the Llandeilo and Bala beds, the prodigious development of life in which had no parallel in the older British formations; and it is important to remember that the fossils of these strata are to a great extent different generically, and almost entirely specifically, from those known in the more ancient formations.

With respect, then, to Lingula, Tremadoc, and Llandeilo and Bala beds, taking into consideration the remarkable breaks in succession not only of species but of genera, together with various physical points of great significance, I have no doubt that actual unconformity exists in this part of the series, and that there is a necessary connexion between these facts. Indeed, this unconformity, if not seen, is, as already stated, easily inferred, for while in Merionethshire the Lingula flags are from 5,000 to 6,000 feet thick, only 11 miles north, near Llanberris, their thickness is only 2,000 feet, this reduction having been produced probably by *unconformable overlap.* Close to Menai Straits, if present at all, the Lingula beds are still thinner, and in Anglesey they are absent altogether, so that the Llandeilo and Bala beds lie directly and, I believe, unconformably on Cambrian strata. To show that this is not a mere local accident, let me recall the circumstance that in Ireland and in Sutherlandshire the Lingula flags are also absent, and Llandeilo beds lie unconformably on Cambrian grits and conglomerates.

For the remainder of the Silurian formations I cannot easily do better than quote what I have said elsewhere on the subject, with modifications.*

Llandovery or Pentamerus-beds.—The evidence of the physical and palæontological relations of the Llandovery beds to the underlying strata is as follows.

In North Wales, in Montgomeryshire and Merionethshire, the Lower Llandovery beds, being sandy, are easily separable from the slaty Bala beds beneath, and there is no very direct evidence of unconformity between them; but in South Wales, near Llandovery,† there is proof at Noeth-Grug of a slight unconformity between them and the black slates on which they lie.

The Upper Llandovery rocks, however, behave in a very different manner. These range interruptedly from Marloes Bay in Pembrokeshire through Caermarthenshire to Builth, the Longmynd, and the typical Silurian country of Shropshire; and everywhere they rest quite unconformably on older rocks, lying sometimes on the denuded edges of the Lower Llandovery beds, sometimes on Caradoc Sandstone, and at Builth and the Longmynd on the highly contorted and denuded Llandeilo and Cambrian strata.

The lists of the Geological Survey show that about 90 species of fossils are

* Anniversary Address of the President to the Geological Society, 1863.

† Observed and mapped by Mr. Aveline.

known in the Lower and Upper Llandovery strata of Wales and its neighbourhood. These, taken together, are, on the whole, so distinctive that it has been proposed to elevate the strata in which they occur into a Middle Silurian series; and, at all events, their stratigraphical and palæontological relations are so important that I give the following analysis of the fossils of the Llandovery beds, showing their palæontological relations to the Caradoc and Wenlock strata, which has been prepared by Mr. Etheridge and myself from his lists of the fossils of the British Islands stratigraphically arranged, and which will shortly be published.

TABLE OF THE FOSSILS OF THE LLANDOVERY BEDS OF WALES AND THE NEIGHBOURHOOD, SHOWING THEIR RELATION TO THE CARADOC SANDSTONE AND THE WENLOCK SHALE.*

FOSSILS.	CARADOC SANDSTONE.	LOWER LLANDOVERY BEDS.	UPPER LLANDOVERY BEDS.	HIGHER SILURIAN STRATA.
Trilobites.				
Acidaspis Brightii	+	+	+	+
Calymene brevicapitata	+	+	+	+
Cheirurus bimucronatus	+	?	+	+
Cybele verrucosa	+	+	—	—
Encrinurus punctatus	+	+	+	+
Homalonotus bisulcatus	+	+	—	—
Illænus Bowmanni	+	+	+	—
Illenopsis Thompsoni	+	+	+	—
Phacops Caudatus	+	?	+	+
——— Stokesii	—	+	+	+
Brachiopoda.				
Atrypa reticularis	—	+	+	+
——— crassa	—	+	+	—
Leptæna sericea	+	+	+	+
——— transversalis	+	+	+	+
Orthis biloba	+	+	+	+
——— caligramma	+	+	+	+
——— elegantula	+	+	+	+
——— porcata	+	+	+	—
——— reversa	+	+	+	+
——— testudinaria	+	+	+	—
Pentamerus lens	+	+	+	+
——— lyratus	—	+	+	+
——— oblongus	—	+	+	—
——— undatus	+	+	+	—
Rhynchonella borealis	+	+	?	+
——— Grayii	—	+	+	+
——— nucula	—	+	+	+
Spirifer elevatus	—	—	+	+
——— trapezoidalis	+	+	+	+
——— octoplicatus	—	+	+	+
Strophomena antiquata	+	+	+	+
——— applanata	—	+	+	+
——— arenarea	—	+	+	+
——— compressa	+	+	+	+
——— corrugata	—	+	+	+
——— depressa	+	+	+	+
	24	35	34	27

* When a fossil passes from any formation into the next but one above or below, it is considered that it probably occurs in the intermediate formation, and its place is marked thus ?

Fossils.	Caradoc Sandstone.	Lower Llandovery Beds.	Upper Llandovery Beds.	Higher Silurian Strata.
Brachiopoda—cont.	24	35	34	27
Strophomena euglypha - -	—	+	+	+
——— pecten - -	+	+	+	+
——— tenuistriata - -	+	+	+	—
——— bipartita - -	+	+	+	—
Lamellibranchiata.				
Pterinea retroflexa - -	—	+	+	+
——— planulata - -	—	—	+	+
——— demissa - -	—	—	+	—
Actinodonta cuneata -	—	—	+	+
Ctenodonta deltoidea -	—	—	+	—
——— Eastnori - -	—	—	+	+
——— lingualis - -	—	—	+	—
——— rhomboidea - -	—	—	+	—
——— subæqualis - -	—	—	+	+
Cucullæa antiquata - -	+	?	+	+
Goniophora cymbæformis -	—	—	+	+
Lyrodesma cuneata - -	—	—	+	—
Modiolopsis antiquata -	+	?	+	+
Mytilus mitilimeris - -	+	+	+	+
Orthonota amygdalina -	—	—	+	+
——— inornata - -	—	—	+	+
——— semisulcata - -	+	?	+	+
Gasteropoda.				
Cyclonema crebristria -	+	+	+	+
Euomphalus alatus - -	+	?	+	+
——— sculptus - -	—	—	+	+
——— tricinctus - -	—	+	+	—
——— subcarinatus - -	—	—	+	—
Holopella cancellata - -	—	+	+	—
——— conica - -	+	?	+	—
Murchisonia angulata -	+	+	—	—
——— cancellata - -	+	+	—	—
——— gyrogonia - -	+	+	—	—
——— inflata - -	—	—	+	—
——— pulchra - -	+	+	+	—
——— simplex - -	+	+	+	—
Platychisma Williamsii -	—	+	?	+
Raphistoma lenticularis -	+	+	+	—
Trochonema trochleata -	—	+	+	—
——— tricincta - -	+	?	+	—
Turbo tritorquatus - -	—	+	+	+
Bellerophon bilobatus -	+	?	+	—
——— carinatus - -	+	+	+	—
——— dilatatus - -	+	+	+	+
——— expansus - -	+	?	+	+
——— obtectus - -	—	—	+	+
——— subdecussatus -	+	?	+	—
Pteropoda.				
Conularia Sowerbii - -	+	+	?	+
Cephalopoda.				
Lituites Cornuarietes -	+	?	+	+
Orthoceras annulatum -	+	+	+	+
	49	67	79	52

Fossils.	Caradoc Sandstone.	Lower Llan-dovery Beds.	Upper Llan-dovery Beds.	Higher Silurian Strata.
ıalopoda—cont.	49	67	79	52
s approximatum -	—	—	+	—
ineatum - -	+	?	+	—
›sum - -	+	?	+	+
ɜx - - -	+	+	+	+
ɪuistriatum -	+	+	+	—
eras ventricosum -	+	?	+	+
	54	54←72→66	66←85→55	55

regoing Table shows that, according to existing British lists, there wer Llandovery species. Of these, 54 have survived from the pro- umbers, 576 species named, found in the Caradoc and Bala beds; peculiar to the formation; 66 pass into the Upper Llandovery rocks, ch also pass into the Wenlock shale.

therefore three-quarters of its fossils are found also in Lower rocks, the disappearance of so large a proportion of Caradoc species very great change of conditions. Considering the relative numbers o formations, it is too much to suppose that the older fauna was by the invasion of a few new species from another area, although, s be conformable to each other, this is probably an obvious though ost likely explanation. The suspicious unconformity between Caradoc ɛr Llandovery beds in South Wales points in the direction that in ɜre is a gap, due to upheaval and denudation, unrepresented by strata, the two formations, and that on re-submergence only a few of the aradoc forms survived, to mingle with newer forms at first almost mited in number.

pper Llandovery beds have yielded as yet about 85 species, 66 of cur in the Lower Llandovery rocks. Six species belonging to the re disappeared, and while about 51 Upper Llandovery forms are the Caradoc Sandstone.

ɪsolute unconformity of the Upper Llandovery beds on all below, with change of species, is another remarkable coincidence, and connected with a lapse of unrepresented time; for the Lower trata were, in our area, in places metamorphosed, intensely contorted, , and extremely denuded before the deposition of the Upper Llando- began. Such events involve the lapse of a period of time (unrepre- r strata) which it is almost impossible to exaggerate; and I believe ɜe the result in the loss of old species and the appearance of new. ɡe in this respect is, however, far less both in genera and species than h took place between the Lingula and Tremadoc and Llandeilo beds; fore possibly the smaller changes represent shorter periods of strati- y unrepresented time.

k Shale, &c.—If we now examine the relation of the Wenlock shale ɪper Llandovery beds, we shall find that, out of 85 species, 55, or nearly ɔwards into the former, which frequently overlaps the Llandovery ıch a manner as to leave no doubt of an unconformity that must again , period of unrepresented time, after which we have the vast develop- life of the undoubted Upper Silurian epoch, during which 5,000 'eet of strata were deposited in a period of apparently slow and steady ı.

rmore it is evident, from the sandy character of most of the Llando- a, from the conglomerate nature of part of the upper beds (derived waste of the Lower Silurian rocks), from the comparative thinness,

local character, and repeated unconformities of its members, extending even to the Tarannon shale, that they were formed during an epoch of oscillation of level, and therefore that its component parts only represent fragments of a great intermediate epoch that elapsed between the close of the deposition of the Caradoc Sandstone and the beginning of that of the Wenlock Shale. The main result is, that of about 90 Llandovery species in all, 54 pass downwards into the Caradoc Sandstone, and 55 upwards into newer Silurian formations.

We have now seen that in the whole Silurian series there are six very distinct sets of strata, and five stratigraphical breaks between them, as follows:—

Lingula-flags,—

Between which and the Tremadoc slate there is a break very nearly complete both in genera and species, and probable unconformity.

Tremadoc Slate.

Break very nearly complete both in genera and species, and probable unconformity.

Llandeilo and Caradoc beds.

Large break, especially in species, and probable unconformity.

Lower Llandovery beds.

Break and partial unconformity.

Upper Llandovery beds.

Break and unconformity.

Wenlock Shale, &c.

Each of these breaks, in my opinion, necessarily implies a lost epoch, stratigraphically quite unrepresented in our area, and the life of which is only feebly represented in some cases by the fossils common to the underlying and overlying formations.

But whatever difference of opinion may exist as to the disturbance of the Cambrian, Lingula, and Tremadoc beds before the commencement of the Llandeilo and Caradoc epoch, there can be no doubt that from the top of these strata downwards all the rocks were bent, contorted, and much denuded before the commencement of the deposition of the Llandovery rocks, or at all events of the Upper Llandovery strata. It was the pressure incident to the contortion of these lower strata that induced that first cleavage characteristic of all the Cambrian and Lower Silurian rocks of Wales, in the highly disturbed regions north of the Towey in Carmarthenshire,* and west of the valley of Church Stretton in Shropshire. As we might expect, this cleavage is most intense in the lower slaty strata that, like those of Llanberis and Penrhyn, lie in the centre of the great anticlinal curves, for there the superincumbent weight and vertical pressure of the pile was necessarily greatest, while what may be called the horizontal pressure was going on that produced the contortion and cleavage of the lower strata. At these great depths the component particles of the strata could not, by fracture and shattering, escape that intense force that compressed and turned them on their axes and thus produced cleavage. The great north-east faults are of later date than the contortion of the strata, while many of the smaller ones are clearly connected with it, and when the fractures took place, those parts of both kinds that now cut the surface were deep under ground and unexposed by denudation.

* In Dynevor Park and its neighbourhood north of the Towey a very small tract of country is uncleaved.

A later disturbance of the strata produced a second and more partial cleavage in the Upper Silurian rocks, so well marked at Llangollen and many other places, but at what precise period this occurred I am unable to say, though it must have been before the deposition of the Upper Old Red Sandstone. In that case underneath a thick casing of unconformable Upper Silurian rocks the Lower Silurian strata experienced a second great disturbance, evidence of which is occasionally found in a second set of cleavage planes in the lower Silurian rocks themselves, and also in the partial identity of strike of Lower with Upper Silurian formations.

It is curious how rooted the idea is in some minds that the broad-spreading masses of igneous rocks in the Lower Silurian regions are connected with, and indeed the cause of, the disturbance of the strata amid which they lie; and some who are not far advanced in their geological studies being told that there are volcanic rocks round Llyn Idwal and Llyn Llydaw on Snowdon, at once jump to the conclusion that the sides of these and such like *corries* are the actual walls of Lower Silurian craters, in the hollows of which lakes lie, as in the extinct craters of the Eifel. In reality, such hollows are the result of denudation, and are intimately related to the icy phenomena of a very late period, and indeed in all glacier regions, past and present, high circular hollows like these are exceedingly characteristic. So little, in fact, have the igneous rocks to do with the disturbance of the strata, that, as I have already said, they chiefly consist of lavas and ashes, belonging first to the Llandeilo and secondly to the Bala period, which have themselves suffered contortion and other accidents along with the strata among which they are interbedded. Even the great bosses of porphyry seem often only to be Cambrian and Lower Silurian rocks that have themselves been fused; and while sometimes these appear to have been somewhat affected by contortion, they have certainly been broken by the greater faults like the strata amid which they occur. Lying as they invariably do either amid the true volcanic rocks or in lower stratigraphical horizons, and being for the most part felspathic, some of them may well be the deep-seated masses from whence the lavas and ashes of the volcanoes came; and I do not see why this should not hold, even though they may only in certain instances have been Cambrian or Lower Silurian strata that passed into a state of fusion. The long lines of intrusive greenstone are more puzzling, and perhaps originated in the intrusion of matter into the Llandeilo and Bala beds from more deeply-seated melted matter, but as they are always associated with rocks on the volcanic horizons they are certainly connected with the phenomena of the volcanos, although holding hornblend, they are different from the common lavas and ashes of the time.

Other greenstones, such as the narrow east and west dykes of Llanberis and the Penrhyn state quarries, are of later date, for a specimen from Penrhyn, shown me by Mr. Griffith Ellis, contained a fragment of cleaved purple slate, and these dykes are therefore

of later date than the contortions of the strata that produced the cleavage, and are probably post-carboniferous.

It would be an easy though a long task to extend these descriptions still further, and to show how equivalent Lower Silurian and Cambrian strata crop out from under uncomformable Upper Silurian beds in the areas of the Breidden Hills and in the district of Shelve by the Longmynd, Builth, and St. David's, but though I constantly visited and assisted the officers of the Survey while the work was in progress, these regions, excepting those of Builth and St. David's, rather lie outside the region with which personally I had most to do in mapping, and the more minute details of the districts are therefore less familiar to me. A glance of the map, however, shows that between Caernarvon Bay and Shropshire the lower strata rise to the surface three times in three great anticlinal curves; first at Llanberis, where the Cambrian rocks are the lowest that crop up; the second in Merionethshire, between Ffestiniog and Barmouth; the third in the boss of the Berwyn Hills, and the fourth in the heights of the Longmynd. In the synclinal hollows between the two eastern of these curves Upper Silurian rocks have been partially saved from denudation, for I have no doubt that the greater part of them once spread across the Lower Silurian strata of the whole of Wales and its neighbourhood.*

In that case it is probable that nearly the whole of Wales, before the Upper Silurian rocks were deposited, had suffered denudation as extreme as that which took place in the Longmynd before the formation of the Upper Llandovery rocks, which it is well known in that region lie indifferently on lowest Llandeilo and uppermost Caradoc beds, and, as may be seen in Mr. Aveline's sections across that country,† once covered the topmost parts of the Cambrian rocks of the Longmynd themselves. Whether the Lower Silurian rocks of Wales before that time formed plains of marine denudation worn into undulations I do not know, but I think it probable that they did. However this may be, it seems to me almost certain that at a much later period great plains of marine denudation‡ formed what is now the region of Wales, making table-lands with intersecting valleys, one of which is now the Vale of Clwyd. These table-lands, after repeated changes of the same kind, were, I believe, older than the New Red Sandstone, but the details are too long to be discussed here.§ By denudations, chiefly subærial since that time, the details of the present outlines

* I even think it probable, after vast denudations of the older strata, that the Upper Carboniferous rocks themselves once covered a prodigiously greater part of that vast region than they do at present.

† Six-inch sections, sheet 34, line 2.

‡ For an explanation of this term, see "Lectures to Working Men," 1864, p. 140, Ramsay.

§ The flat top of the Mendip hills, formed of denuded Carboniferous rocks and Old Red Sandstone, formed a part of one of these plains; and the highly contorted Devonian strata of the Rhine and Moselle show like appearances. The phenomena are by no means isolated, but speak of a long period of comparative repose and subsequent tranquil elevation.

of Wales have, I think, been produced, modified probably by short submersions; for though there is no absolute proof that Wales has been beneath the sea since the formation of the New Red Sandstone, except during the Drift period, such submersions may have taken place, their traces having been obliterated. Under any circumstances there has been plenty of time for the cutting out of valleys in old table-lands by the weather, by running water, and by glaciers, for I have no faith in the formation of any of these *existing systems of minor valleys* either by fractures or by unbroken curvatures of the strata. Great valleys between two distinct mountain ranges may be formed in this way, minor ones, I think, rarely or almost never, and then only under circumstances which I have only once seen in the Jura, and which do not exist in Wales. Indeed, I cannot understand how any one can reasonably explain the formation of the Welsh valleys by bending and fracture of beds if he has once realised the idea of the thousands of feet of strata that have been removed by denudation since the contortion of the strata took place.* When that contortion occurred and was finished, the mountain tops, for instance, of the Cader Idris and the Snowdon ranges were still buried deep under many thousands of feet of higher Bala beds, and at a later period, I believe, by an immense thickness of Upper Silurian strata. During enormous geological periods since then, these strata have been slowly removed by denudation and the present surface has been formed, the general result being that the harder rocks now stand out as rugged mountains, not because of extra rending and disturbance there, but because they have been and are more difficult to wear away. Therefore the valleys of the country, chiefly worn out by the drainage of these high lands and dating from times of inconceivable antiquity, are all of later date than the disturbances, and are now in no way immediately connected with them, whether there be faults in the hollows or not; for, like the present surface rocks, the faults themselves when formed were (as far as regards the parts now at the surface) thousands of feet deep in the earth. Faults, however, *in conjunction with denudation*, often determine the direction of valleys by bringing hard and soft rocks together, as, for instance, in the case of the valley of Bala lake, which has been chiefly cut out in soft rocks between two ranges of felspathic porphyry.

To the eye of one who appreciates the physical features of a country there is indeed, on ascending a height, nothing more striking than the average flatness of the tops of many of the hills, especially when the rocks which compose them are of tolerably uniform texture; a flatness, be it remembered, not connected with anything like a horizontal position in the beds, for everywhere

* See an essay on this subject in the first volume of the Memoirs of the Geological Survey, "On the Denudation of South Wales and the Adjacent Counties," Ramsay. In that essay the main object was to show the vast amount of matter removed by denudation after the disturbance of the rocks. In that I believe I succeeded; but I am now aware that I attributed too much to the power of the sea as having cut out many of the valleys of the country, and too little to ordinary subaerial actions.

they are contorted and often stand on end. All Wales shows this feature, from the Towey to the slaty hills that flank Cader Idris and the Arans on the south and east, and even in the mountain land from Cader Idris to the Menai straits, traces of a similar approximate uniformity of height are plain to the experienced eye, showing the relics of an old form of ground, in which deep valleys have been not rent but scooped out. In lower ground, the features of Denbighshire east of the Vale of Clwyd in a remarkable manner agrees with these principles. There in an average table-land, the result of the quiet marine denudation of disturbed strata, innumerable valleys have been cut out of the solid mass, the accumulated drainage of which forms streams of tolerable size, which, from higher to lower levels, have gradually cut through an unfaulted escarpment of Carboniferous limestone on their way to join the Clwyd. Such principles, I am convinced, give, when well considered, the true key to the meaning of the present outlines of the country, and few subjects in physical geology would possess greater interest than a complete account of the denudations by which, *after* disturbance of the strata, Wales assumed its present form.

APPENDIX.

ON THE FOSSILS OF NORTH WALES.

By J. W. SALTER, A.L.S., F.G.S., &c.,

LATE PALÆONTOLOGIST TO THE GEOLOGICAL SURVEY.

June 1865.

LIST OF THE WOODCUTS.

For Description of Plates, see p. 379.

APPENDIX.

A DESCRIPTION of the fossils illustrative of the preceding memoir has been so long looked for, and so many hindrances have prevented its being brought to completion, that a more than ordinary apology is due if after all it should not be so full and satisfactory as may be desired.

I have endeavoured to describe and figure all that I know of the fossils of those obscure strata which lie at the base of all.* They are fortunately for the most part within the North Welch area, and it has been thought worth while to include the few observed in other districts, so as to render the account more complete. I hope, therefore, in this respect my brother palæontologists may find materials worth their notice. But with respect to all the overlying strata, Llandeilo, Caradoc, Llandovery, Wenlock, &c., lists only are given, and the more prominent of the new species figured and described.† A very considerable number of less perfect forms wait for another opportunity.

It would, indeed, be premature to attempt a complete catalogue of the organic remains of the principality. That can be better done when the geology of the southern districts and of Shropshire shall have been described. And it is the less necessary to do this with the mass of the Welch fossils, since there is a very close affinity—nay, identity—between the organic remains throughout the whole region of Wales and those of Siluria proper. This will be abundantly proved by the catalogues given in the sequel.

Even though the Caradoc rocks of Shropshire and those of Snowdon were for the most part deposited under very different conditions of the sea bed, the number of identical species is surprising. The argillaceous slates of Wales, the volcanic grits, the perpetual alternations of calcareous and felspathic beds with sandstone and shale, are conditions as unlike as possible to those of the continuously sandy deposits of Welchpool and Siluria; yet with few exceptions the fossils are identical. It is true the Caradoc rocks of neither of these regions were deposited under deep water. And as the element of depth is found in modern seas to be of more importance than the condition of the sea bottom, it is not to be wondered at that there should be a great similarity between the two districts. The typical Caradoc is unquestionably a shallow-water deposit.

It is the same if we descend into the next formation, the Upper Llandeilo rocks, now clearly understood to be distinct from and inferior to the Caradoc. The originally described limestones of Carmarthenshire and Radnorshire contain a peculiar series, which, differing as it does both in general aspect and specific characters from the fauna of the Bala region, is yet one and the same if the various districts of Llandeilo age be compared one with the other.‡

Of the Lower Llandeilo (the "Arenig or Skiddaw group" of Sedgwick) so much cannot yet be said. But it is a formation scarcely yet known, and here for the first time defined and illustrated so far as the materials are accessible. Yet there is some promise of an identical series, even in such remnants and patches as we have been yet able to examine. There is moreover a positive identity, as has been partly shown by Sir Roderick Murchison in his Siluria,§ between the fossils of the Stiper Stones, and those of the upper Iron-slates of Tremadoc, while the cliffs near St. David's Head have yielded new but related species.

The "Tremadoc slate," though known in but a single district, is so rich in conspicuous forms, that we have been able to separate it into two distinct zones;

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* In reference to the expression of Mr. Salter, "the fossils of those obscure strata which lie at the base of all," I beg to state that according to the classification of the Geological Survey adopted by Sir H. de la Beche and his associates in 1843 the strata thus alluded to are the Lingula flags of the Lower Silurian rocks. These strata have been rendered anything but *obscure*, particularly through the labours of Mr. Salter himself.

December 9, 1865. RODERICK I. MURCHISON.

† I have, however, particularly endeavoured to illustrate those MSS. species mentioned in the Appendix to Siluria, 2d ed., so far as they relate to the Welch district.

‡ The distinctness and superposition of the Caradoc to the Llandeilo was never fully proved till the publication of the last edition of Siluria, the distinction having been in many cases rather a petrographical than a zoological one. But the whole of the Llandeilo and Caradoc strata of Wales having been examined by the Survey, and the Llandovery rocks clearly separated from both, the superposition of the Caradoc became manifest in the typical sections.

§ 2d ed., 1859, pp. 49–53.

and each of these, thanks to the zeal and liberality of two gentlemen, have been pretty fully illustrated. To Messrs. Ash and Homfray of Portmadoc our very hearty thanks are due, both for independent and original work, and for their free communication of materials and help when they found I was engaged in tracing out the limits of this new formation. Happily we do not need a name, for the "Tremadoc slates" were put in their true place by Sedgwick in the account he gave of these rocks in 1847. The first actual section including them was the work of a geologist now deeply buried in law books, but whose work has always been worth recording,—Mr. E. Davis, formerly of Presteign.* But Mr. Davis did not distinguish the group nor find a fossil. Professor Sedgwick found two, one of which was from the Tremadoc, and one from the Lower Llandeilo rocks. The true relations of the beds have only lately been cleared up. But their position, with respect to the Lingula flag below and the Lower Llandeilo group above was clearly shown in 1851 by Sedgwick.†

In the Lingula zone, wherever it is seen, a perfect uniformity is manifest. As it ranges round the great nucleus of North Wales (the Merionethshire anticlinal of Sedgwick) the characteristic Lingulæ and Trilobites are everywhere found. At St. David's in Pembrokeshire the same shells were detected, after a careful search, in their right places. And where this old formation shows itself in scanty outliers further eastward,‡ the characteristic species are still present.

I shall now, in ascending order, notice the characteristic fossils of the several formations. These will give a basis for comparison of our own protozoic faunæ with the published results of other labours. I dare not myself attempt this task now; for though it would be easy to indicate roughly the results of many years' thought, they would be worthless without giving the evidence. It has, perhaps, been too much the custom to give the results first and the data afterwards. If I were inclined to do this I should have some apology in the fact, that having had for years to work all but single-handed at our palæozoic stores, I have been able to do little more than roughly catalogue the whole, and render all the species, described or undescribed, accessible to any earnest student. The Silurian fossils are arranged in their chief stratigraphical divisions, and in their natural history order, but I am afraid to say how many of the less perfect forms still remain under their generic titles only. Catalogues made during this labour include all the published and unpublished forms, and greatly extend the range of the known species. I trust these may soon be circulated, as they are already prepared for the printer.

CAMBRIAN (Geol. Survey).

No fossils have yet been found in the grits and sandstones of the mountain district between Harlech and Barmouth. And the numerous exposures of these rocks in the neighbourhood of the Bangor slate quarries yielded nothing, to a rather close search, except the very obscure fossils figured below.

The only organic remains discovered in the Cambrian rocks of Britain up to the year 1855 were the two species of *Oldhamia*, now well known in systematic works. They were regarded by their discoverer as more probably *Polyzoa* than *Zoophytes*. Their alliance with the former group is strongly questioned by one of the best authorities on the subject, Mr. Busk,§ see also p. 281.

Since these were found, I have myself been fortunate enough to detect abundant traces of former life in the highly inclined strata of the Longmynd. A reference to the Quarterly Geological Journal for August 1856 and January 1857, will show the character of these fossils, which are not repeated here, because they will be fully figured in Part 2 of this memoir.

They consist chiefly of impressions, which were once evidently the burrows of marine worms. Like those of the ordinary *Arenicolæ* of our coast, they had both entrance and exit holes, so that the hollows (and the corresponding tubercles which are the casts of these on the lower surfaces of the beds) are

* *See* Quart. Geol. Journ., vol. 2, p. 70.
† Pal. Foss. Woodw. Mus. 1851, 1st fasciculus, advertisement.
‡ At Pedwardine, near Brampton Bryan, Shropshire, and in the Malvern Hills. We have figured one or two of the Malvern trilobites in Pl. 5.
§ In a letter which he allows me to quote, Mr. Busk says, "I can make little of them, except " that there is an absence of any characters by which they can be said to belong to the Polyzoa. " . . . I am inclined to regard them as corallines, something perhaps after the type of *Acetabularia*, and if, as the appearance of the cast seems to indicate, the rays of the frond were " united by a membrane or web, it would be much in favour of their being vegetable, and decisive against their being Polyzoa."

always in pairs. A reference to the small right hand figure below will explain this arrangement, which is very constant. (Woodcut 2.)

These hollows occur in such multitudes, and through so great an extent in the strata of the Longmynd (a full mile in vertical thickness), as to impress us with the belief that annelide life was very abundant in Cambrian times.

Immediately after I had found them, my friend Dr. Kinahan searched vigorously the well exposed rocks of Bray Head, and found even more conclusive evidence, which he has published in the procedings of the Geol. Soc. of Dublin for 1857 and 1858. He found the meandering burrows of the worms themselves, the conical mound and its central aperture striated by the movements of the worm; in some cases the burrow was of a coiled form, in others vertical, or oblique, or horizontal, in the ancient "silt."

I have referred to these fossil-prints beyond the district now described, because there can be no doubt that a like careful search in the finer strata of the Barmouth district would yield some or all of these markings. The fine-grained sandstone of Moel-y-ci near Bangor, where I found the specimen here figured, is also well worth search, and an earnest and hopeful examination will often detect markings that escape us when we have reason to believe the field a barren one.

Foreign Cambrians.—A most interesting discovery has of late been made in Bohemia in this formation.

The Etage B. or Azoic rocks of Mr. Barrande had been as yet quite neglected, as our own barren Cambrians were in former days. But Dr. Antonio Fritsch, keeper of the Geological and Fossil collections in the Royal Bohemian museum, Prague, having made special research for Cambrian fossils in this formation, has been rewarded by discovering (1861), in thin slabs of sandstone, marks which can hardly be distinguished from our own Longmynd fossils. The same double burrows, the same vertical tubes on the edges of the slabs, testify to the existence of annelides in the fine sediment of these most ancient sea shores.

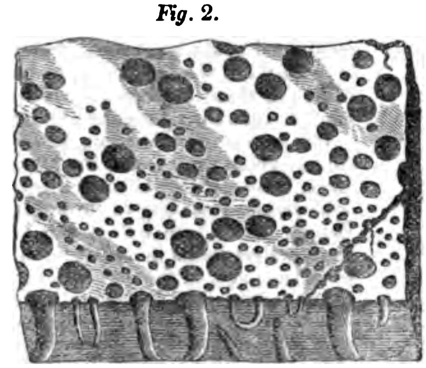
The progress of research will bring these, and probably other forms, to light in other countries, in the Huronian rocks of Canada—for instance.

That the long cylindrical and tortuous bodies found in the older rocks are not the remains of seaweeds is certain from their form and structure, since by no conceivable process could sand or sandy silt be made to *replace accurately* a soft cellular mass. The late Professor Forbes was disposed to refer many of them to *Alcyonarian* zoophytes; but this explanation is unnecessary, since we know of no remains of *Alcyonaria* in old rocks. Every requirement of the fossil is met by the supposition that we see the excreta of the worm as it bored its way through silt and sand, carrying the material of one bed into that of the next, and threading them together into a tough and pasty mass.* The burrows are nearly always of a coarser texture and a lighter colour than the matrix.

Fig. 1.

1. Filled up burrows of marine worms in Cambrian sandstone. Moel-y-ci, Bangor (*Chondrites*, Salter, Quart. Geol. Journ., vol. xii., p. 246.)

Fig. 2.



2. Surface of bed, with the double burrows of annelides. From the Stiper Stones, and other Silurian rocks. The surface also represents, on a larger scale, the marks on the strata in the Longmynd.

* The term "Fucoids" will have to be all but expunged from our nomenclature. The w[illegible] known Fucoid bed of the Upper Ludlow rock is a tangled and matted mass of Annelide [illegible]

As the list of Cambrian fossils for Britain is so very scanty, I will here enumerate them all. They have lately been reviewed in the Geological Magazine by Mr. Baily, of the Irish Geological Survey.

Name and Reference.	Locality.
PLANTS.	
1. *Oldhamia antiqua*, Forbes. Journal Geol. Soc. Dublin, 1848; Siluria, 2d. ed., p. 28, fig. 2, Kinahan, Trans. Roy. Irish Acad., vol. 23, p. 557, figure 5. — var. *discreta* (*O. discreta*), ib. p. 556, Plate 26. f. 1–3.	Carrick McReilly mountain, Wicklow; Bray Head, Wicklow.
2. *O. radiata*, Forbes, ibid., 1848, Kinahan, l.c., p. 557, figures 3–5, 8–10. Plate 26. f. 4, 5.	Ditto. ditto.
O. —— sp.? Plate 26, f. 6, 7.	Ditto. ditto.
ANNELIDES.	
3. *Arenicolites didymus*, Salter. Quart. Geol. Journal, vol. xii., pl. 4, fig. 1 (1856).	Longmynd, near Church Stretton.
4. *A sparsus*, ibid. Quart. Geol. Journal, vol. xiii., pl. 5, fig. 2.	Ditto.
5. *Histioderma hibernicum*, Kinahan. Journ. Geol. Soc. Dublin, 1858, pl. 6.	Bray Head, Wicklow.
6. *Haughtonia pœcila*, id., in the Nat. Hist. Reviewand Quart. Journ. Science, July 1859.	Bray Head, Wicklow.
7. *Scolites* (vermicular burrows), Kinahan. Journ. Geol. Soc. Dublin, 1857, pl. 1, 1858, pl. 7; Salter, 1856, description and figure *supra*. Woodcut, f. 1.	Wicklow; Bangor; Longmynd.
CRUSTACEA.	
8. *Palæopyge Ramsayi*, Salter, Quart. Geol. Journ., vol. xii., 1856, pl. 4, fig. 3.	Callow Hill, Longmynd.

I do not very strenuously maintain this last fossil to be a trilobite; but it is either a caudal shield of one, or else a broad body segment of a phyllopod allied to *Hymenocaris*. I feel persuaded of its being a crustacean, and hope to have further evidence when the description of the Longmynd district shall be ready.*

LINGULA FLAGS.

Above the Cambrian grits near Bangor, which contain the tracks of worms mentioned in the last pages; dark coloured slates, with much iron, forming the lower band of the Lingula flags, have as yet proved barren of organic remains; while the thick sandstones which overlie them are rich in the characteristic Lingula (or rather Lingulella†) of the formation.

But in the corresponding beds of iron-stained slate, intercalated with sandstones, which wrap round the Merionethshire Cambrian rocks, there are abundant trilobites, chiefly of small size; and the more sandy strata that succeed (the equivalents, according to Professor Ramsay, of the Lingula sandstones of the Bangor district) are rich in this peculiar shell, and moreover contain two or three perfect forms of crustacea of a primordial type. These were described some time ago, in the decades of the Survey, and in a communication read by myself to the British Association at Belfast so far back as 1852. They were

rows. For a notice of the extensive part played by worms in the Palæozoic rocks, *see* Quart. Geol. Journ., vol. xiii., p. 205; also vol. xvi., p. 222. In some observations made a few years back on the sea coast of Pembrokeshire, I found that rocks much permeated by these burrows were tougher, and resisted the wear of the sea better than many others.

* This has been erroneously attributed, by Mr. G. E. Roberts, in the January number of the Geological Magazine, to *Ceratiocaris*, and I believe all the balance of evidence inclines to the view that it may be an abnormal trilobite. But if possibly a phyllopod, it is certainly not a *Ceratiocaris*. (Jan. 1865.—J.W.S.)

† It has been found necessary to institute a new genus for this fossil. It partakes almost as much of the character of Obolus as it does of Lingula. Mr. Woodward first pointed out its chief character; and I will describe it in the sequel.

found by the officers and collectors of the Survey, and have since been largely collected by Messrs. Ash and Homfray, of Portmadoc.

But the researches of Barrande, especially among the lower groups of the Silurian system, had meanwhile invested these few organisms with a double interest. In a visit paid to this country in 1851, for the express purpose of comparing his rich materials with our published and unpublished types, he recognized the "Lingula flag" of Sedgwick as the exact equivalent of his primordial stratum (*Etage* C.); and he has since, in many separate memoirs, successfully carried out this comparison, not only for Britain but for the European and American Continents.

To him therefore belongs the whole credit of originating the term, and defining the fossil characteristics of this "primordial zone," a group of rocks which grows in distinctness and geological importance day by day. Of its foreign equivalents a word or two only can be said further on.

His discovery was admitted fully, and adopted by the Survey, so soon as a re-examination of the typical district had been made. The evidence, as it stood in our catalogues, did not, at the time M. Barrande announced his belief, warrant us in coming to the conclusion that this zone was perfectly distinguishable by its organic remains. The fossil species had scarcely been collected in Britain: the upper members of the formation, the most important, as will be seen, for the fossil evidence, had not been recognized as distinct from the overlying formations of black slate, then supposed, and with great probability, to be inseparable from the ordinary Lower Silurian groups. And lastly, there seemed to be no good reason for supposing the black slates of Malvern with Olenus to be so much older than the rocks which overlay them, though this point was essential to M. Barrande's supposition.*

As the small collections made during the progress of the Survey did not warrant the immediate application of M. de Barrande's views to the British Islands, and as certain anomalies presented themselves, (the few genera we had then obtained were not all of a primordial type,—see Brit. Assoc. Reports, l.c., p. 58,) I was directed by Sir H. De la Beche to re-examine a portion of the Lingula flag series, with special regard to the fossil succession. I found that the group was divisible into three distinct zones, two in the lower, and one in the upper division. The following is the ascending order:—

——	1853.	Fossils.
Lower Lingula flags.	1. A lower series of black slates, pyritous, with many beds of intercalated sandstone near the base. Maentwrog Waterfall, &c., &c.	*Agnostus princeps*, *Olenus cataractes*, *Lingulella Davisii*.
	2. A middle thick sandy series, the typical 'Lingula flag' of Tremadoc, Ffestiniog, Dolgelly, &c. Carnedd Ffiliast, Bangor.	*Olenus micrurus*, *Hymenocaris*, *Lingulella Davisii* in great abundance, *Cruziana semiplicata*.
Upper Lingula flags.	3. An upper black slate, with hard pyritous bands, especially at the base, thickly crowded with fossils. Tremadoc, Maentwrog, and W. of Ffestiniog.	*Olenus alatus*, *O. scarabæoides*, *Agnostus princeps*, several sp. of *Conocephalus*, *Ellipsocephalus?* † *Orthis lenticularis*, *Dictyonema? sociale*.
	(The species are figured on plates 1–5.) These beds passed up into a series of dark shales with iron beds, the equivalent of the *base* of the great igneous series of Merionethshire; and in these occurred genera which might be compared with the Llandeilo period. Pl. 6–10.	(The list of fossils has now been rendered more extensive, *see* p. 249, and the formation named "Tremadoc slates"), pp. 250–53.

* *See* his Note "Sur l'Extension de Faune Prim.," Bull. Soc. Geol. Fr., 2nd ser., vol. xiv., 439.

† This was a loose fragment, and came from higher beds. The species had lost its characteristic head, and now proves from better specimens to be a subgenus of *Conocephalus*, or rather *Conocoryphe*, as the genus must now be called.

These fossil data, limited as they were by the scanty time at our disposal and the want of collectors, were sufficient to remove the difficulties felt before as to the supposed admixture of types respectively characteristic of the *primordial* and *Llandeilo* faunas (Etages C. and D. of M. Barrande).

The new view was then at once adopted by the officers of the Survey, though from the complicated nature of the ground, and the doubt felt as to the public utility of drawing fresh lines of demarcation, it was not thought advisable to give a distinct colour to the formation. The Primordial fauna was publicly recognized by Prof. Edw. Forbes, palæontologist to the Survey, from the president's chair of the Geological Society (Anniversary Address, 1854, vol. 10, p. xxxi.) He there distinctly announced the division of this group into an upper and lower, as the result of the search made by me in 1853.* (Siluria, 2d ed., p. 47.)

The appointment of Professor Forbes, in 1854, to the Edinburgh University chair, and the pressure of many duties thrown upon my inexperience since that time, have prevented my doing much more than watch with interest the development of this important fauna in America and elsewhere. In 1860 I obtained leave to revisit North Wales, as there were still some points unsolved as to the passage of the group into the Llandeilo rocks above; and the former trial had led me to expect a rich harvest of new species. I had, for part of the time, the hearty eager assistance of the gentlemen above mentioned, Messrs. Homfray and Ash, and the services of our chief collector, Mr. R. Gibbs. When I had made out the succession and planted the collector, I traced the three subdivisions westward to Criccieth † and eastward to Ffestiniog, and found abundant organic remains, especially in the upper subdivision.

This upper subdivision, a black slate, rests somewhat abruptly on the lower and more sandy strata of the Lingula flagstones, but passes up insensibly into a formation which I shall next describe—the Lower Tremadoc slate. It is almost impossible to draw a boundary which shall define the upper margin of this black slate, which in its best development is about 250 or 300 feet thick.

A line taken at that elevation above the Lingula Sandstones will be found to tally with a zone occupied by a peculiar net-like fossil, described on p. 331 as *Dictyonema sociale.* This abundant fossil marks an important boundary between what I must consider the *primordial* zone, and the base of the overlying Lower Silurian formations. As *Dictyonema sociale* is occasionally found in the black slates beneath this horizon, and never above it, while its nearest ally is a primordial fossil in Sweden, I include it in these lists as the uppermost zone of the "Lingula flags."

We may now therefore proceed to give a catalogue, with a few notes appended, of the Lingula flag fossils, so far as yet known, dividing them into an upper and a lower zone.‡

Lower Lingula Flags.

[I. Black slate and sandstone with ash-beds, followed by (II.) a thick series of quartzose and ashy (Lingula) flags. *Foreign equivalent.*—Alum slates of Sweden and Norway.]

Name and Reference.	North Wales. — Bangor, Tremadoc and Dolgelly Districts.	South Wales, and other British Localities.	Foreign Localities.
Annelida.			
Scolites,§ Worm burrows. Pl. 4, fig. 13; pl. 3, fig. 4.	Carnedd Ffiliast, S.E. of Bangor; S. of Maentwrog and Ffestiniog, on sandstones.	—	—
Helminthites,§ Worm tracks.	Do.	—	—
Scolecoderma ‖*tuberculata*, n. sp. Pl. 5, fig. 24.	Borthwen, Tremadoc.	—	—
Cruziana semiplicata, Salter (1853). Pl. 3, f. 1–3.	Carnedd Ffiliast, Bangor; W. of Tremadoc; Maentwrog.	Beneath the Stiper stones (or an allied species) (1856).	—

* In a recent memoir devoted to a review of the status of the primordial zone, M. Barrande suggests this division of the series for America, as it has also been indicated in Sweden by M. Angelin.

† The best section to show in a small space the entire succession of the Lingula flags is that of Y-Graig-ddu, a promontory a few miles E. of Criccieth. A plaited, broken, and faulted arch of the black Lower Lingula beds, is there surmounted on either side and over its north end by a zone of hard Lingula flags, and these on their western side by the entire succession of the Upper Lingula flags, Tremadoc slate, &c.

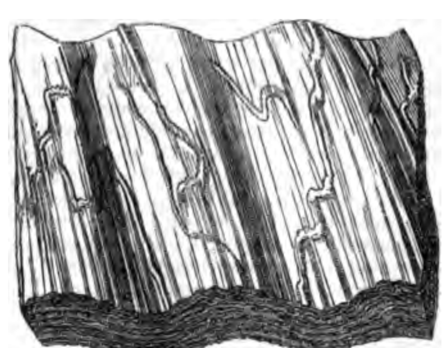
‡ Descriptions of the species will be found with the plates further on.

§ Quart. Geol. Journal, vol. xiii., p. 205. ‖ *See* Descriptions, p. 293.

Name and Reference.	NORTH WALES. — Bangor, Tremadoc and Dolgelly Districts.	SOUTH WALES, and other British Localities.	Foreign Localities.
CRUSTACEA.			
Hymenocaris vermicauda, Salter (1853). Pl. 2, fig. 1-4, and tracks, Pl. 1.	Pentrefelen, W. of Penmorfa; Borth, W. of Portmadoc; Dolgelly, Carnarvon?	—	*A. pisiformis*, in Alum slates, Sweden.
Agnostus princeps, Salter. Pl. 5, fig. 1; Pl. 4, figs. 2, 11.	Maentwrog waterfall, and other places near Ffestiniog.	- - -	
Microdiscus punctatus, Salter, Quart. Geol. Journ., vol. xx., pl. 13, f. 11.	S. of Maentwrog - - -	Do.	—
Olenus micrurus, Salter. Pl. 2, figs. 5, 6.	Marchllyn-Mawr, near Llanberis; Trawsfynydd; Dolgelly (at gold mines); Treflys; Borth; Tremadoc, &c.	—	—
Olenus cataractes, n. sp. Pl. 5, fig. 23.	Maentwrog waterfall. Treflys, E. of Criccieth.	—	—
Paradoxides Hicksii (*Forchhammeri*), Salter. Pl. 4, fig. 12.	Locality uncertain, Tremadoc or Dolgelly.	- - -	Alum slates, Sweden.
Paradoxides Davidis, Salter. Quart. Geol. Journ., vol. xx., pl. 13, f. 1-3.	N. of Dolgelly - - -	St. David's Head.	—
Holocephalina, new sp. for genus, *see* Salter, Quart. Geol. Jour., vol. xx., pl. 13, f. 9.	S. of Maentwrog - - -	Porth Rhaw, St. David's.	—
Linguella (*Lingula*) Davisii, M'Coy. Pl. 2, figs. 7-12.; pl. 4, fig. 14. (*L. ovata*, M'Coy, is said to be from Ffestiniog, probably this species is intended.)	Carnedd Filiast, Bangor; Marchllyn-Mawr, Llanberis; Tremadoc; Ffestiniog; Dolgelly; (everywhere in the middle band of the Lingula flags; rare in the lower black slates at Maentwrog.	Whitesand Bay, near St. David's Head, Pembrokeshire.	Alum slates, Christiania ? (Kjerulf).
Linguella lepis, n. sp. Woodcut 11, p. 334.	Borthwen?	Abundant in the overlying Tremadoc slate.	—
Theca obtusa, n. sp. Woodcut 17, p. 352.	Maentwrog waterfall and Tafarn Helig.	St. David's Head.	—

A few notes on the above list may be necessary. And first of the worm tracks and burrows. These ever-recurring markings are conspicuous in beds which otherwise show no traces of organic bodies. In the fine section of the lowest Lingula flags, seen to advantage along the course of the Maentwrog river, all the lower beds of the formation, viz., thin beds of iron-stained sandstone and many of the slaty schists also, are permeated by them. These beds are often affected by an imperfect cleavage, which does not actually split them, but plaits the surfaces in a remarkable way, such as may be easily mistaken for organic remains. Over these large plaits the worm tracks are very conspicuous. When running with the plaits they are magnified by them; when across they are broken up by them, something in the way indicated in this woodcut.

Fig. 3.



Plaited surface of a bed of *Lingula sandstone*, with the tracks of worms upon it. S. of Maentwrog, river side (Lower Lingula flag)

These surface markings may be properly called by the term *Helminthites*, while the solid filled-up burrows, represented in Plate 3, and Plate 4, f. 13, are distinguished by the name of *Scolites*, terms which were proposed by myself in 1857 as convenient definitions of very common phenomena. In the same way I now propose the term *Scolecoderma* for those cases where the membranous or slimy tube of the worm itself is preserved, and this may easily be recognized, since in these cases the tube is always pressed flat. Such are common in all rocks, and need some recognition. But except in marked instances where surface ornament is preserved, I think it would be mischievous to give specific names.

I believe, for reasons given in the descriptions, that *Cruziana* is the filled-up burrow of a marine worm. Pl. 1, is believed to represent the tracks of the peculiar and very abundant phyllopod crustacean which I have called *Hymenocaris* from its evidently very thin texture. These tracks are not uncommon on the sandy surfaces of the middle (or quartzose) bands of the Lingula flags. Especially are they abundant in the neighbourhood of Pentrefelen, or between that place and Wern on the Criccieth road. In a small quarry nearly opposite Wern Gate, these tracks occur, and the same quarry is one of the best localities for the *Hymenocaris* itself. The fine specimen, from which we figure afresh the caudal appendages, is from thence.

This locality is near the top of the Lingula flags, properly so called, and it is in the thin ripple-marked micaceous flags of this part of the series that the greatest number of fossils occur. The beds are largely rippled, and in the ripple hollows patches of drifted sand and broken Lingulæ occur, showing the action of the tide or superficial currents on these old sandbanks, for such they certainly were. The annelide markings cross them in all directions, and the frequent sharp indentations, made, as I believe, by the tail-prongs of *Hymenocaris*, help to keep up the idea of a shallow sandy bottom, thickly covered with living animals. The *Lingulella* is most abundant in these upper beds, in some localities so close that you cannot lay a finger between the shells, but in others more scattered.

Trilobites are far from common in the Lingula flags itself; but in certain beds of the lower Lingula slates, which are full of iron, and contain some volcanic ash, the *Agnostus princeps* occurs in millions, together with an *Olenus*, of a species which I find to be distinct from any yet described. At Pen-y-foel mountain, which overhangs the *Velyn Rhyd* fall, they are better seen than in any of the numerous neighbouring localities which yield them. Here the whole hill seems to be made up of pressed and altered iron slate, full of the distorted specimens of these little trilobites. Hardly a hand specimen but has many of them. I have represented a slab in its natural state in Pl. 4, f. 11, and a more perfect specimen is given by its side. There was some doubt if it were the same species which is so common in the alum slates of Sweden, and I now find it has distinct characters. Here, as there, the *Agnostus* is accompanied by a species of *Olenus*, a true primordial fossil.

As showing how rich this old fauna may be expected to prove, I may here mention that the *Oleni* of the lower black slates, those of the Lingula flag itself, and those of the upper black slates, are all distinct. The exact place of the *Paradoxides* is now known: it occurs a hundred feet or more above the base of the black slates, and has been detected both at Dolgelly and in South Wales (Quart. Geol. Journ., vol. xix. p. 275).

Hymenocaris appears to be a far more plentiful fossil than at first supposed. It evidently affected sandy shallows rather than a deeper and muddy sea-bottom. In the fine slaty layers which form the capping of the Lower Lingula flags* it is most abundant, and generally in a good state of preservation. The coarser grits and sandstone which form the high grounds west and south-west of Tremadoc have not yielded any specimens; but wherever the finer upper layers occur, both Hymenocaris and the Lingulæ occur in plenty. In the cove of Borth, near Portmadoc, and at Wern, near Penmorfa, it is found perfect. (Pl. 1, 2.) Messrs. Ash and Homfray have perfect specimens.

The only shell, excepting *Discina* and Lingula, which is known to occur in our N. Welch Lower Lingula flags, is a large species of *Theca*. It is imper-

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* Grey slaty beds commence and terminate the series of Lingula flag sandstones; in several localities as a passage into or from the black slate beds. They are sparingly fossiliferous (chiefly containing *Oleni*) below the sandstones, but filled to repletion with *Lingulæ* at the top. The *Oleni* may be well seen in the grey slaty layers along the estuary at Aber-ia, opposite Port Madoc.

fect, but is figured and described in p. 352. More perfect specimens have since occurred S. of Maentwrog.* The genus occurs on the same horizon in other countries. There are several Brachiopod shells in South Wales (St. David's).

The range and persistence of the *Lingula* (or rather *Lingulella*) is remarkable; it is found everywhere in quantity throughout the Tremadoc country, and the vale of *Ffestiniog*, and through the wild moory ground as far east as Llyn Dywarchen, where it was detected by Professor Ramsay; and I found it there in plenty in 1853, and at Pont Nant-y-Lladron on the Bala road. East of that line the hard Lingula flags do not occur, but followed to the south-west and south it has been found by the surveyors everywhere to hold the same horizon, that is to say, in the middle or quartzose series of the Lingula flags. I have myself found the *Lingulella* near the base, in company with trilobites, near the Maentwrog waterfall as above noticed, but it was small and ill developed there, as it is also in the beds which overlie these Lingula strata. Yet, strange to say, it reappears in the upper portions of the next or overlying formation, of nearly its full size and character. This will be more specially noticed in speaking of the Tremadoc slates.

The distant locality of Whitesand Bay, St. David's, shows that its range southward is considerable. Its discovery there and inland by Mr. Aveline and Mr. Gibbs confirmed the conclusion already drawn on physical grounds that the whole succession of the lower beds might be traced in that headland; and later research by myself and Mr. H. Hicks have largely added to the lists.

Upper Lingula Flags.

Black shale, with pyritous bands, and some ashy beds.

So soon as we rise into the overlying black slates or Upper Lingula flags the fossils suddenly augment in number and variety. The following is the list, and I have included the Malvern species.

Name and Reference	North Wales Districts. — Tremadoc.	South Wales, and other Districts.	Foreign Localities.
Annelide markings - - -	Rare. S. of Maentwrog -	St. David's Head.	—
Olenus alatus, Boeck. Pl. 4, fig. 8a.	Penmorfa Church, W. of Tremadoc; Carreg-wen, W. of Portmadoc.	- - -	Sweden, in alum slates.
(*O. bisulcatus*, Phill. Mem. Geo. Surv.; vol. ii., pt. 1, p. 55).	- - - -	Malverns, White-leaved Oak.	—
O. scarabæoides, Wahl. Pl. 4, figs. 1–5. (*O. spinulosus?* Phill. Mem. Geo. Surv., vol. ii., pt. 1, page 55).	Carreg-wen, S.W. of Portmadoc.	White-leaved Oak, Malvern hills.	Sweden, in alum slates.
O. flagellifer, Angelin? Pl. 5, figs. 8, 9.	Carreg-wen - - -	- - -	Sweden, alum slates.
Olenus, sp. —— Pl. 5, figs. 10, 11, 12.	Carreg-wen.	—	—
Ol. serratus, n. sp. Pl. 5, figs. 6, 7.	Carreg-wen - - -	- - -	*O. spinulosus*, Sweden, is a close ally.
Olenus humilis, Phill. Mem. Geo. Surv., vol. 2. pt. 1, pl. 55.	- - - -	Malverns (*as above*).	—
Conocoryphe† (*Conocephalus*) *invita*, Salter, Siluria, 2nd ed., p. 47, foss. 7., pl. 4, figs. 5–7., pl. 7, fig. 5.	Penmorfa Church - -	- - -	[*C. Emmerichii*, *Barr.*, from Bohemia, is closely allied.]
Conocoryphe abdita, n. sp. Pl. 5, fig. 13.	Ogof-ddu, Criccieth.	—	—
Conocoryphe (*Ellipsocephalus*) *depressa*, Salter, Siluria, 2nd ed., p. 47, f. 2.	Wern, Tremadoc.	—	—
Conocoryphe, sp., Pl. 5, figs. 14, 15	Ogof-ddu, Criccieth.	—	—
Conocoryphe, sp., ib., fig. 16 -	Ogof-ddu, Criccieth.	—	—
Conocoryphe ? —— sp., ib., fig. 17 -	Penmorfa Church.	—	—
Dikelocephalus ? (or *Centropleura*) *celticus*, n. sp. Pl. 5, figs. 21, 22.	Ogof-ddu, Criccieth -	- - -	*Centropleura* . . . . *Angelin*, Sweden, closely allied.

* Found in company with new Trilobites lately by Mr. D. Homfray.

† The reasons for adopting this name will be given in the description of the plates.

Name and Reference.	North Wales Districts. — Tremadoc.	South Wales, and other Districts.	Foreign Localities.
D.?? discoidalis, n. sp. Pl. 5, figs. 18, 19.	Ogof-ddu, Criccieth -	- - -	*Dikellocephalus? planifrons*, Billings, Quebec, very nearly allied.
D.?? sp. ——— Pl. 5., fig. 20	Do. -	- - -	Do. do.
Agnostus princeps, n. sp. Pl. 4, figs. 2, 11; Pl. 5, fig. 1.	Penmorfa Church; Ogof-ddu, Criccieth; Carreg-wen, Borth; Portmadoc.	Malverns; St. David's (in the Tremadoc slate).	*A. exsculptus*, Ang. is closely allied, Alum slate, Sweden.
Dictyonema sociale, Salter. Pl. 4, fig. 1. (In uppermost layers only.)	Gelli-fwyog, Ffestiniog; Railroad above Plas Oakley; Borth wood, Portmadoc; W. side of Moel-y-gest.	Pedwardine, near Brampton Bryan.	*D. flabelliformis*, Russia and Sweden; a close ally.
Lingulella lepis, n. sp. Woodcut, 11, p. .	Borth; Cefn-cyfarnedd; W. side of Moel-y-gest.	—	—
——— *Davisii*, M'Coy, Pl. 2, f. 7–12.	?	—	—
Orthis lenticularis, Dalm. Pl. 4, figs. 8, 9, 10.	Penmorfa Church; Ogof-ddu.	- - -	Sweden; abundant.

The Dictyonema occurs rather above the level of the black slate. But the last fossil (*Orthis*) is found in the greatest profusion at the very base of the black slates, exactly where they repose upon the quartzose layers filled with *Lingulæ*. In the roadside brook, a few yards beyond Penmorfa Church, I found them in 1853, and again, in 1860, obtained slabs of this gregarious species. As the bed lies just at the base of the wall, and a fault occurs close by, it may very easily be overlooked. A better locality is the cliff of Ogof-ddu near Criccieth, where, on the west side of the jutting promontory of Craig-ddu a complete section (from the *Lingula* flags to the upper Tremadoc slates) may be obtained. Here, at the junction of the black slate with the Lingula flag, the same *Orthis* occurs in myriads, the fossils standing out in bright orange colour (peroxide of iron) from the dark pyritous slate. This locality is one of the most easily worked and the most prolific of all the Upper Lingula flag localities. The above list will show that several of the forms have only yet been detected there—*Conocoryphe, Dikelocephalus*, &c. *Orthis lenticularis* and the *Agnostus* are there in millions.

A very good fossil locality is to be found on the farm of Carreg-wen, half a mile west of the village of Borth. From this spot nearly all the species of *Olenus* were obtained, and large specimens of *Agnostus princeps*, which is our English representative of the very abundant *A. pisiformis* of Sweden. This again is one of the few points where a true section from the fossiliferous Lingula flag to the Tremadoc series can be traced, for east and west of it the ground is much faulted.

Although the black slate can be traced all round the outcrop of the true Lingula flags, fossils have only been detected in a few places; but this, I am persuaded, is only for want of searching, and more pleasant and profitable ground to work I do not know in the British Islands.

Above this formation lies a group of beds to which very little attention has been paid, but to which, in his careful Survey of Wales, Professor Sedgwick has given the name of Tremadoc Slate. He obtained but a single fossil from its upper member only, nor could we then estimate the full importance of this group, which overlies the Lingula flag and distinctly passes under the Lower Silurian rocks.

Tremadoc Slates.

The formation which immediately succeeds the black Lingula slates, has been already traced as to its course in the preceding memoir. But a few words must be said about this band, which so intimately connects the Lingula flags with the ordinary Silurian rocks, and which is nevertheless so distinct as to its fossil characters from either.

If we were to judge by mineral character alone, we should undoubtedly draw the chief line of separation above the hard arenaceous Lingula flags, where the peculiar bivalves characteristic of that formation become scarce enough. Yet the zoological change does not take place here, for with the recurrence of the

black band last described the characteristic genera of the primordial zone return, unmixed with those of true Lower Silurian character.

The black slates do not terminate abruptly, but gradually lose their deep tint, and become grey about the horizon of the flags which contain the *Dictyonema*.* This character continues and increases upwards through the beds which contain the following fauna. The beds are also harder, contain flaggy layers here and there, but are not at all coarser, nor otherwise much different from those of the black slate series, except in colour and fossil contents.

The characters of the formation may, as before said, be seen in the sea cliffs of Ogof-ddu near Criccieth, where the harder grey Tremadoc slate, with many lines of ashy material, is easily seen to overlie and pass down into the black slate, full of fossil remains. But here the newer rock is very barren of fossils, and we must refer to the opposite side of the anticlinal axis, and examine the sections near Moel-y-gest, and other places in the Tremadoc district, in order to find the fossiliferous zones.

Lower Tremadoc Slate.

The best localities yet known for fossils are the following:—1. Borthwood, and the meadow slopes on the north side of it, towards the foot of Moel-y-gest, where trilobites and shells are abundant. This mass of rock is let in by extensive faults among the Lingula flags of the neighbourhood, but the escarpment, small as it is, shows an excellent section upwards from the black slate, full of fossils, through the Dictyonema beds, to the shell and trilobite beds which cover the top of the hill, and run down its sloping surface to the north.

[On the bye roads that run from Portmadoc to Treflys and the neighbourhood, the grey, often flaggy, but generally dark shaly and thin-bedded Tremadoc slates, and the lighter coloured and harder beds of Lingula flags may be easily compared; for they lie close together, and it is not always easy to draw a line between them, the lines of fault bringing them close together without the intervention of the black slate, yet the *fossils* are totally distinct.]

2. At the village of Penmorfa the same beds are seen, and are richly fossiliferous. They are dark and earthy, yet not black, or highly pyritous as the upper Lingula flags are, and may be easily followed from a little above the village church along the hill side to the new railway (for slates) from Hendre-ddu, Brynkir. There a considerable thickness of the lower Tremadoc slates comes into view, and the passage downward to the black slate is not obscure. Above, the section is cut off by faults.

3. A considerable tract of ground running along the west flank of Moel-y-gest exhibits these rocks, but as yet only the lower or intermediate (*Dictyonema*) layers are known to contain fossils. These are plentifully seen at the farm of Cefn Cyfarnedd, and in the walls at Mr. Matthew's seat, Y-Wern.

4. They are seen underlying the upper Tremadoc beds on the west side of Portmadoc Harbour; and at the rock called Trwyn-Cae-Iago, east of Borth, contain the *Psilocephalus innotatus*

5. East of the estuary, the new road cuttings on the beautiful demesne of Aber-ia reveal fine sections of these beds, which are again conspicuous in the grounds of Castle Deudraeth, and may be traced further east through the rough district skirting the Maentwrog road. They are seen in good sections about the village of Deudraeth, where they are quarried for buildings, and contain the characteristic fossils. They keep the course of the Maentwrog road as far as the turnpike gate, and may thence be followed through the wood and along the course of the railway above Plas Oakley. Above Maentwrog Inn they may also be followed for a while, but their character gradually changes to that of a felspathic slate, in which condition they continue all the way to Ffestiniog. And a little before reaching that village they may be found (at Gelli-fwyog) with the characteristic *Dictyonema* at the base, all but joining the Lingula flags, a very thin band only of the black slate (and that somewhat altered in character) being interposed.

6. But little is known of their east course, but the abundance of the small *Lingulella lepis* in dark earthy slate quarries on the Bala road beyond Pont Nant-y-lladron, in immediate superposition to the Lingula beds, indicates the

* About 150 feet above the black slate (D. Homfray). I think this, however, is rather too high an estimate.

presence there of the Lower Tremadoc group. They should be sought for along this line, and further southward by Dolgelly. I think I saw them at Cader Idris in 1865, when examining the gold district.

UPPER TREMADOC SLATE.

The beds into which the dark grey earthy slates last mentioned pass up are not easy to distinguish from the Lingula flag. But they are lighter coloured, often pale grey, and of a flinty texture, occasionally intercalated with ashy layers. Near the top, hard beds of grey sandstone come in, immediately beneath which are the principal beds of fossils, though there are several other fossiliferous lines throughout. Without entering into details of the beds, the following sketch may be given of the distribution of the fossils through the various parts of the Tremadoc series. In descending order they are as follows,—

—	Formation.	Localities.	Remarks.
LLANDEILO ROCKS.	15. Ash beds - - -	Llanfrothen - - -	No fossils found.
	14. Ashy slate - - -	Ty-obry - - - -	
	13. Blue-black fine slate -	Tan-Yr-Allt - - -	
LOWER LLANDEILO, Murch. (ARENIG GROUP, Sedgw.)	12. Thin layers of black iron-stained slates lying on	Ty-obry - - - -	*Dendrograpsus* and *Diplograpsus*; *Dionide*; *Calymene*; *Æglina*; *Palæarca*.
	11. Thick grits, with some felspathic beds near the base.	Garth Hill, Penrhyn; Ynystwyn, Portmadoc; flanks of Yr Altwen.	(Beds equivalent to those of the Stiper stones, Shropshire.)
UPPER TREMADOC SLATES.	10. Hard bluish flags - -	Garth Quarries, Penrhyn; Pen-bryn-Melyn, Penrhyn; hill side above Deudraeth.	*Lingulella Davisii*; *Angelina*; *Asaphus*; *Cheirurus*; *Ogygia*; *Conularia*; *Orthoceras* *Lingulocaris*; *Centrotheca*.
	9. Soft thin-bedded sandy shales.	Marsh opposite Deudraeth; shore at Minffordd; marshy ground about Tremadoc (by many faults).	—
	8. Hard bluish flat-bedded slate, alternating with many beds of similar slate; but with a "pencil" cleavage and with some flaggy layers.	Penamser, Penrhynllwyd; Tu-hwnt-yr-bwlch.	*Asaphus*; *Theca*; *Orthoceras*; *Conularia*.
	7. *a**? Thick ash bed - - Pisolitic iron ore.*	Morfa Lodge, &c.	—
	6. Hard tough beds in a thick series, quarried for building stone at	Portmadoc Quarries - -	*Theca*; *Ogygia*; *Asaphus*; *Angelina*; *Cheirurus*; *Ogygia*; *Ampyx*.?
	5. Pencil rotchy slate, black, a thick series.	W. side of Portmadoc Harbour	*Lingulella lepis*; *Bellerophon*.
LOWER TREMADOC.	4. Hard blue rock, sometimes almost massive (and with beds and layers of pisolitic iron here and there **?); lines of felspathic ash frequent.	Trwyn-cae-Iago; south and east crest of Moel-y-gest; ridges of Borthwood; Plas-yn-y Penrhyn and hills ranging to Deudraeth. (Ynys-Calch and Pen-syflog, with iron ore?)	*Psilocephalus*; *Lingulella lepis*; *Conocoryphe*.
	3. Thick series of iron-stained dark slates passing down into black slate below.	Above Penmorfa Church? railway above Penmorfa; Moel-y-gest, W. side; Borthwood; Aber ia; and various places along the slate railway to Maentwrog.	*Psilocephalus*; *Niobe*; *Theca*; *Conocoryphe*? *Dictyonema*.
	2. Tough bluish beds, only developed locally.	2 miles W. of Penmorfa -	*Psilocephalus*; *Dictyonema*? *Ogygia*.
UPPER LINGULA FLAGS.	1. Black slate, about 200 feet thick.	Penmorfa Church; W. side of Moel-y-gest; Carreg Wen, W. of Borth.; Aber ia; Castle Deudraeth; and various places on the Ffestiniog road.	For fossils, *see* list in p. 249.

* I believe there are not two bands of iron ore, but of the place of that ore I am not yet cer- [redacted]

distribution of the *genera* in the zones of the Tremadoc slates has been in the above table. The following is a list of all the species observed formation in Wales. And I have added (p. 256,) a separate table of ɔpermost beds, which are here termed Lower Llandeilo flags, as they ɩeen so described by Sir R. I. Murchison. (They belong to the Arenig of Sedgwick.)

Name and Reference.	Lower Tremadoc.	Passage Beds.	Upper Tremadoc.
le tubes - - -	Everywhere, as burrows or tracks.		Yr-alt-wen.
ɔcaris lingulæ-comes. Pl. 10,	- - - -	- -	Tuhwnt-y-bwlch, Garth.
caris? insperatus. Woodcut 6	- - - -	Penmorfa	——
us. Woodcut 5 - -	- - - -	- -	Garth.
us princeps - - -	Penmorfa Church -	- -	Penclogwyn.
us Frederici. Pl. 8, f. 1–3. -	- - - -	Llanerch	Garth; Penclogwyn.
ephalus furca, head. Pl. 8,	Moel-y-gest (Mr. Ash)	——	——
l of do.? f. 10 - - -	Penmorfa - -	- -	Penclogwyn.
us Sedgwicki. Pl. 7 - -	- - - -	- -	Penclogwyn; Garth; Portmadoc; Tuhwnt-yr-bwlch; Under Garth, &c.; Deudraeth; Ynys-Tywyn.
prænuntius. Pl. 8, f. 5 -	- - - -	- -	Penclogwyn.
yphe verisimilis. Pl. 6, f. 13	- - - -	Penmorfa village.	——
ides. Pl. 8, f. 6 - -	- - - -	- -	Garth.
essa. Pl. 6, f. 1–3 - -	Wern; Borthwood; Penmorfa.	——	——
ta, Pl. 8, f. 7 - - -	- - - -	Penmorfa village.	——
impar. Pl. 8, f. 4 - -	- - - -	- -	Penclogwyn.
ɔhalus inflatus. Woodcut 8	Cae-Iago; Llanerch; Penmorfa; Borthwood.	——	——
latus. Pl. 6, f. 9–12 - -	Borthwood; Tydynllwyn Gate; Llanerch.	——	——
s Homfrayi. Pl. 8, f. 11–14 -	- - - -	Penmorfa village.	Moel-y-gest; Tuhwnt-yr-bwlch; Garth; Penclogwyn.
is. Pl. 8, f. 15 - -	- - - -	Llanerch	Tuhwnt-yr-bwlch; Penrhynllwyd; Penclogwyn; Cae Ednyfydd.
Homfrayi. Pl. 6, f. 5–8 -	Deudraeth Church; Ogof-ddu; Penmorfa; Borthwood; Tyn-y-llan.	Llanerch field, near house.	——
scutatrix. Pl. 9, f. 1 -	Penmorfa road -	- -	Garth; Penclogwyn; Portmadoc.
lla Davisii. Pl. 2, f. 7–12; f. 14.	- ? -	- -	Deudraeth; Garth, abundant.
. Woodcut 11 - -	Wern; Borthwood; Trwyn-Cae-Iago; east of Pont-nant-y-lladron, Bala road.	- -	Under Moel-y-gest; Garth.
ɔhon Arfonensis. Pl. 10, f. 6–8	- - - -	Llanerch	Moel-y-gest; Garth; Penclogwyn.
istriatus. Pl. 10, f. 9, 10 -	- - - -	id. (Mr. Ash.)	Moel-y-gest.
ria Homfrayi Pl. 10, f. 11–13	- - - -	- -	Tuhwnt-yr-bwlch.
(Centrotheca) alata. Pl. 10,	- - - -	- -	Tuhwnt-yr-bwlch; Garth.
perculata. Pl. 10, f. 22–24 -	Borthwood; Tyn-y-dre; Tyn-y-llan.	——	——
rculum of do. - -	Borthwood, Tyn-y-dre.	——	——
s. Pl. 10, f. 15, 21 - -	Borthwood; Tyn-y-llan.	——	——
osa, Pl. 10, f. 19, 20 - -	Do. do.	——	——
- - - -	- - - -	- -	Penclogwyn; Garth; Tuhwnt-y-bwlch; Moel-y-gest.
ras sericeum. Pl. 10, f. 4, 5	- - - -	Llanerch?	Tuhwnt-yr-bwlch; Garth.
ras præcox. Pl. 10, f. 3 -	- - - -	Llanerch.	——

ɩaps the most characteristic of all the fossils of these rocks are, the *Niobe ayi* and *Psilocephalus* in the lower division, and the *Angelina* and *us affinis* (or *A. Homfrayi*) in the upper.

These four trilobites are met with wherever the strata are well seen. The *Niobe* is a large oval trilobite, and has a strong Lower Silurian look about it with the general aspect of an *Asaphus*, much flattened it is true, but still characteristic, it unites the labrum of an *Ogygia*, and may therefore be considered as intermediate between these genera. *Psilocephalus* again, with its tumid extremities, the head scarcely divided at all into lobes, recalls the aspect of *Illænus* very strongly, though it has the characteristic pleuræ of *Asaphus*, and is in many respects intermediate between that genus and Illænus.*

Agnostus is of the rarest occurrence. But a peculiar form or two of the primordial genus *Conocoryphe*, or of one closely allied to it, are common. The *Conocoryphe depressa* (formerly referred by me on Barrande's suggestion to *Ellipsocephalus*) is still doubtfully referred to the primæval type. And in all the species above the Lingula flags the generic type is obscure. In this, as in so many cases, the influence of time is rather a thing *felt* by the palæontologist, as he patiently threads his way through a monograph of species, than appreciable by the outside man of science, even though he be a good naturalist, who merely views the lists and compares the per-centages of fossil forms. It requires more than these to make up the sum of the differences between any two given fossil faunæ. Much might be said on this gradual change of type. It requires a volume properly to illustrate it, and every worker in fossil species knows it to be true, or else our means of identifying remote groups of strata would be scanty indeed.

With the *Agnostus* the Lingulæ have also disappeared from nearly all the lower beds of this formation, although a small and possibly distinct species, which I have called *Lingulella lepis*, is abundant enough. But the most characteristic of the shells are the numerous specimens of *Theca*, small triangular pointed shells which no naturalist doubts to have been ancient forms of Pteropod life. One of the species is furnished with an operculum, a new fact in the history of the division of Pteropoda to which *Theca* belongs.

As we rise into the beds which I have called Upper Tremadoc, some of the species above named linger on awhile, mixed with the new forms of *Orthoceras*, *Bellerophon*, and *Asaphus*, characteristic of the upper division. But it is only in the passage beds (as seen at Llanerch west of Portmadoc, and south of Garth on the east side of the estuary) that such a mixture has been detected. Penmorfa Village,—not the church,—is another locality, and the southern side of the crest of Moel-y-gest mountain contains the same beds.

[On the locality marked Llanerch on the above list, which occurs in two columns, one marked as passage beds, it may be necessary to explain that by the intervention of faults, which range through the farm of Llanerch, all the lower formations are brought up so as to lie within the range of a field or two. This locality is the best I know of for showing the passage from the Lower Tremadoc slate with *Niobe* and *Psilocephalus*, to the upper with Asaphus, Orthoceras and Bellerophon. At the junction the *Niobe* occurs with the last named genera in a hard flinty slate.

Mr. Homfray, in a note enclosing a sketch, says that at the base occurs *Niobe* and *Psilocephalus*, and further up he finds with *Niobe*, *Orthoceras sericeum*, *Cyrtoceras*, *Bellerophon*, and *Asaphus*. Mr. Ash found there *Cyrtoceras præcox* and *Bellerophon multistriatus*.]

But the true Upper Tremadoc rocks are characterized by a crowd of new species. The *Niobe* and *Psilocephalus* are replaced by *Asaphus* and *Angelina*. The latter indeed is a most remarkable and characteristic fossil, and though allied to *Conocoryphe*, cannot, I think, be with reason referred to that genus. It is found in the greatest abundance in the rich quarries of Garth, and further eastward towards Deudraeth; and no doubt a search along the flanks of the hills which skirt the vale of Ffestiniog would show it everywhere. With it occur many new species, chiefly the *Asaphus Homfrayi* and *A. affinis*, if those two species be not identical. At Portmadoc quarries it occurs frequently, and west of the town, at the unpronounceable farm of Tu-hwnt-yr-bwlch, good specimens are obtained. *Cheirurus Frederici* more rarely accompanies it in all these

* A Darwinian would say, that occupying as it does an inferior position both to *Asaphus* and *Illænus*, it might easily be supposed to be the progenitor of both. I have but little to say against such a supposition.

places. Agnostus too, but rarely. Two species of the genus Conocoryphe, their forms, as above said, less characteristic than those of the primordial zone, are found. Even an Olenus, *O. impar*, is present, but so disguised as to look like a species of *Remopleurides*. Lastly, a small *Ampyx* has been found by our formerly zealous correspondent, Mr. Ash, to whom we owe so much of the palæontology of the district. The shells are as distinct from those of the Lower Tremadoc, as they are from those in the volcanic series above. There are species of *Theca*, but they are distinct from those of the lower beds. One of them is a remarkable form with long projecting spines. There is more than one species of *Bellerophon*; a *Conularia*, as large as any that has yet been discovered elsewhere, of most fragile texture; an *Orthoceras* with close septa, and a curved shell which I cannot but refer to the convenient genus *Cyrtoceras*. It is the earliest known of the shelled Cephalopoda, and is of peculiar interest. It occurs at the base of the Upper Tremadoc, in the beds of passage before referred to.

Lower Llandeilo.

The foregoing list only refers to the typical portion of the Tremadoc formation. But above the grits of Garth and Penrhyn, and from that point eastward as far as Arenig Mountain, a still higher set of beds is richly fossiliferous. And as the species in these beds are all of them distinct (with the exception of six Graptolites and one shell) from those of the true Llandeilo flags, it might be proper to class them with the uppermost portion of the Tremadoc formation. But again they are no less distinct from the Upper Tremadoc fossils, and they form therefore a distinct and peculiar zone, which fortunately it is easy to recognize. It is entangled in the lower portion of the volcanic grits and ashes which play a conspicuous part in North Wales.* The following is a complete list, and is derived from our cabinets and from those of Messrs. Homfray and Ash, but chiefly from the collection made in 1860 by myself and our collector Mr. R. Gibbs.

There are no distinct beds of passage with fossils between the Upper Tremadoc and the Lower Llandeilo, and for this reason:—Everywhere along the Portmadoc district a thick bed of grit (comparable I believe only to the Stiper Stone rocks) intervenes to cut off the volcanic upper series from the true Tremadoc slates. This bed of grit, under various conditions, may be traced all along Yr-allt-wen above Tremadoc, and across the estuary, it forms the brow of the Garth, and thence ranges towards the high ground along the curve of the Ffestiniog railway. It is felspathic everywhere, and seems to indicate the commencement of a new state of things, a fact no less plainly indicated by the new fossils introduced. In the black slates immediately overlying these grits at Garth, we find *Graptolites* in plenty, *Homalonotus*, *Asaphus*, and *Calymene* among trilobites; *Æglina* also and *Dionide*, truly Lower Silurian forms; together with new species of *Conularia*, *Palæarca*, &c.; while a little to the eastward, among the lower parts of the volcanic rocks of the Manod Mountains, we have the *Calymene parvifrons* and the *Trinucleus Murchisoni*; and still further east these are accompanied by the *Ogygia Selwynii*, the fossil above all others which particularizes the Lower Llandeilo rocks of Shelve, in Shropshire, and which is found with other fossils, in a similar slate, in S. Carnarvonshire. It is not known as a foreign species.

There is thus no doubt of the horizon of these uppermost rocks. They are quite distinct from the Tremadoc rocks of Sedgwick, and have been already claimed as Lower Llandeilo by Sir R. I. Murchison. They are the Arenig and Skiddaw group of Sedgwick, and have their equivalents, as I have elsewhere shown, in the upper part of the Quebec group of Canada, and in the Graptolite shales of Victoria. (*See* also Geology of Canada, p. 932, Montreal, 1863.)

I have, after due consideration, given a list here of the species from Shropshire, for the following reasons. Several of them have already been partially described and figured, but not sufficiently so. Some of the more characteristic are given for comparison's sake in pl. 11*a*, and lastly it is desirable at once to show that the species of the Tremadoc slate proper can no longer be identified with them.

* And this is their position also in Shropshire, west of the Stiper stones.

List of Lower Llandeilo Fossils, Wales and Shropshire.

Name and Reference.	Upper Tremadoc.	S. and N. Wales. — Lower Llandeilo.	Shropshire. — Lower Llandeilo.	Upper Llandeilo.
Scolithus linearis. Pl. 11 B, f. 27	- -	- - -	W. of Stiper Stones.	
— sp.	- -	- - -	Do.	
Helmintholithes. Pl. 12, f. 2	- -	- - -	Do.	
Encrinite, pentagonal stem, Pl. 11 B, f. 9.	- -	- - -	Do.	
Beyrichia, sp.	- -	- - -	Do.	
Agnostus Morea, n. sp. (Decade ined.)	- -	- - -	Do.	
— sp. Woodcut 7	- -	Tai-hirion.	—	
Calymene parvifrons. Pl. 12, f. 3	- -	Ty-obry; Manod-bach.	—	
Ogygia peltata. Pl. 12, f. 8	- -	St. David's Head	—	
O. Selwynii. Pl. 9, f. 2-6; pl. 11 B, f. 5.	- -	Tai-hirion; Llanfaelrhys; Hengwrt uchaf.	W. of Stiper Stones, (abundant).	
Cheirurus Frederici. Pl. 8, f. 1-3	Garth; Tremadoc.	- - -	Do. ?	
New genus like *Ogygia*	- -	- - -	Do.	
Æglina caliginosa. Pl. 11 A, f. 10	- -	Ty-obry.	—	
Æ. grandis. Pl. 12, f. 11	- -	St. David's Head	—	
Æ. binodosa. Pl. 11 B, f. 3	- -	- - -	W. of Stiper Stones.	
Illænus, sp.	- -	- - -	Do.	
I. perovalis. Siluria, 2d edit., pl. 4, f. 13, 14.	- -	- - -	Do.	
Illænopsis Thomsoni. Pl. 11 B, f. 1	- -	- - -	Do.	
Trinucleus Murchisonæ. Pl. 11 B, f. 4.	- -	- - -	Do.	
Dionide atra. Pl. 11 A, f. 9	- -	Ty-obry.	—	
Diplograpsus pristis. Pl. 11 A, f. 1, d. e.; pl. 12, f. 1.	- -	Tai-hirion	W. of Stiper Stones.	S. Wales.
D. mucronatus. Pl. 11 A, f. 6; pl. 12, f. 1.	- -	Ty-obry.	—	Do.
D. teretiusculus. Pl. 11 A, f. 3	- -	Do.	—	Do.
D. bicornis. Pl. 11 A, f. 1 B	- -	Ty-obry; Ty-ddyn Dicwm.	—	Do.
D. ramosus. Pl. 12, f. 1; pl. 11 A, f. 1 A.	- -	Do. do.	—	Scotland.
Didymograpsus geminus. Pl. 11 B, f. 8.	- -	- - -	W. of Stiper Stones.	
D. hirundo. Pl. 11 B, f. 6, 7	- -	- - -	Do.	
Fenestella. 3 sp.	- -	- - -	Do.	
Graptolites sagittarius. Pl. 11 A, f. 2.	- -	Llanfaelrhys.	Scotland.	
Dendrograpsus furcatula. Pl. 11 A, f. 5.	- -	Ty-obry.	—	
Lingulella lepis. Woodcut 11	- -	Do.	—	
Obolella plumbea. Pl. 11 B, f. 10	- -	- - -	W. of Stiper Stones.	
— sp. (*L. attenuata* olim). Pl. 12, f. 7.	- -	Llanfaelrhys.	—	
— sp. Pl. 12, f. 6	- -	Do.	—	
Discina, sp.	- -	- - -	W. of Stiper Stones.	
Orthis calligramma. Pl. 11 B, f. 11, 12; pl. 12, f. 5.	- -	- - -	Do.	N. and S. Wales.
— sp. (branched ribs). Pl. 11 B, f. 14.	- -	- - -	Do.	
— *alata?* Pl. 11 B, f. 13	- -	- - -	Do.	
Ctenodonta, sp.	- -	Ty-obry.	—	
— sp.	- -	- - -	W. of Stiper Stones.	
Palæarca amygdalus. Pl. 11 B, f. 17	- -	- - -	Do.	
P. socialis. Pl. 11 A, f. 13	- -	Ty-obry.	—	
Redonia anglica. Pl. 11 B, f. 15	- -	- - -	W. of Stiper Stones.	
Ribieria complanata. Pl. 11 B, f. 16	- -	- - -	Do.	
Ophileta, sp. Pl. 11 B, f. 21	- -	- - -	W. of Stiper Stones.	
Theca simplex. Pl. 11 B, f. 22-26	- -	- - -	Do.	
T. vaginula. Pl. 10, f. 14	- -	Tai-hirion.	—	
— sp.	- -	- - -	W. of Stiper Stones.	
Bellerophon hippopus. Pl. 11 B, f. 2.	- -	- - -	W. of Stiper Stones.	
— n. sp.	- -	- - -	Do.	
Conularia corium. Pl. 11 A, f. 11	- -	Ty-obry.	—	
C. margaritifera. Pl. 11 A, f. 12	- -	Do.	—	
Orthoceras Avelinii. Pl. 11 B, f. 18	- -	- - -	W. of Stiper Stones.	
O. encrinale. Pl. 11 B, f. 19, 20	- -	- - -	Do.	
— sp.	- -	Ty-obry.	—	

In 1843 or 1844 Professor Sedgwick and myself collected, west of Arenig Mountain, the characteristic *Calymene parvifrons* and *Ogygia Selwynii*. But the species were not properly described by me till 1847. In the same year Professor Sedgwick noticed the occurrence of an *Asaphus* and some *Graptolites;* in the upper beds of what he then termed Tremadoc Slate. But though he saw that the beds lay below the mass of the Welsh slates, he did not attempt to bring them into parallel with any of the formations described by Sir R. I. Murchison in his larger work, nor were the fossils then known in Shropshire.

I was more fortunate in 1853, for I found there was a small but peculiar fauna in these rocks, distinct both from the Caradoc or Bala beds above them, and even from the Llandeilo formation as known elsewhere in Wales. And when in 1859, the 2nd edition of Silurian appeared, the strata were termed Lower Llandeilo by Sir R. I. Murchison, and were made to be equivalents of the lead-bearing rocks west of the Longmynd and the Stiper Stones, which rocks are full of fossils.

The list from both these localities was but scanty, but Sir Roderick's and my own researches in the Stiper Stones country had brought to light a large series of fossils distinct from Llandeilo types; and two of these fossils (the *Calymene parvifrons* and *Ogygia Selwynii*) were identical with some I had before described from the highest beds, then so called, of the Tremadoc slate. (*See supra.*)

As will be seen by a comparison of the present lists with the slight notice I was able to supply to the work above quoted, the different stages of the Tremadoc slate were not, in 1853, made out by fossil evidence. Hence the Shelve rocks were necessarily compared with the whole series, and an important point, with regard to the palæontology of the Stiper Stones, was lost. The age of those rocks (even including the Stiper Stones themselves) could not be greater, and must be less, than that of the Upper Tremadoc, as these are undoubtedly later than the Lingula flags. As the fossil evidence is decisive of this point, so is the physical structure perfectly explicable on this view, which must be discussed when the Shropshire district is described.

Meanwhile, as a point of comparison for the two rocks (and also for the sake of figuring and describing properly the few species noticed in Siluria), a single plate of Stiper Stones fossils, pl. 11*b*, is added, and the identity of several of the species with those of the Lower Llandeilo will be evident enough.

The strata overlying the Lingula flags in St. David's Bay, Pembrokeshire, which were well searched by our collector, Mr. Gibbs; and again in 1862, by Mr. Lightbody, Mr. J. Lee, and myself, yielded only a *similar*, not an identical series of fossils, and I have therefore included them with some slight doubt in the list.*

For the same reasons that have made it desirable to figure and describe a few of the Shelve fossils, I have added figures of these,† as they certainly occupy a lower horizon than the well-known Llandeilo rocks of other parts of Pembrokeshire.

The few species collected at Llanfaelrhys, Carnarvonshire, occurring in flaggy beds which resemble the Tremadoc slate, are introduced here with little doubt. When figured three years back in our pl. 12, they were believed to be of the age of the Lingula flag. Those from St. David's Head in the same plate, were also regarded as belonging to the upper portions of the Lingula flags, but are now much more properly identified with the Lower Llandeilo rocks. It is most interesting to observe, in a series of beds comparatively new to science, lying below the true Llandeilo flags and above the Lingula flags, how great a diversity obtains in localities not far apart in the fossil contents. The inference is, that a great harvest of undiscovered species remains to be reaped, and many new beds to be discovered in all these localities.

UPPER LLANDEILO ROCKS (Llandeilo flag proper).

The evidence for the existence of this series of rocks in North Wales is not complete, as has been shown by Professor Ramsay in the preceding memoir.

* They are, however, of types very similar to those of the Arenig or Lower Llandeilo, and are undoubtedly distinct from the fauna of the overlying Llandeilo beds of Abereiddy Bay. The St. David's geologists are at work upon them at present.

† They were originally figured with the "Tremadoc slate or Lower Llandeilo" in Sir R. I. Murchison's work. Siluria, 2d edit., p. 53, Foss. 9.

Nevertheless a great band of black slate, quarried at many points for roofing slate (Ffestiniog Quarries, &c.), has been described by Sedgwick and by the Survey as underlying the Bala or Caradoc strata, and thus occupying a position equivalent to that of the Llandeilo flag. It is of interest, if possible, to prove it equivalent by fossil forms. Unfortunately, the materials are but scanty, but a fossil found near Bangor and others in the slates which overlie the Arenig porphyries, are identical with those of the Upper Llandeilo rocks elsewhere; and one or two of the species do not agree with those of any higher formation.

The lists had better be given first, and a few comments on the species afterwards. I have included those of the black slates of Anglesea, though there is some little doubt if they be the equivalents of the dark earthy slates east of Arenig Mountain. There are certain species in them which are but rarely found in Llandeilo strata, *e.g.*, the *Asaphus Powisii* and *Phacops apiculatus;* but the former is certainly found, though rarely, in Llandeilo flags in South Wales. The latter is, so far as known, exclusively Caradoc; but the multitudes of a dwarf variety of *Orthis calligramma*, pl. 22, which give a Caradoc aspect to the grits, are not at all exclusive, for a similar assemblage is to be found in the volcanic Llandeilo grits of Builth. And the Graptolites strongly remind us of the Llandeilo flags. Indeed I do not know of *Diplograpsus teretiusculus** in higher beds.

Name and Reference.	North Wales.	Other Llandeilo Localities in Wales.	Remarks on other Localities.
Stenopora fibrosa, Goldf. Siluria, 2d ed., pl. 40, figs. 6, 7.	Garn, E. of Arenig; S. side of Arenig; 1 mile N.W. of Llanerchymedd; Treiorwerth.	Pembrokeshire	Wexford, in Llandeilo rocks.
Favosites (large tubes)	Fron-oleu, 3 miles S.E. of Llangefni, Anglesea.	—	—
Ischadites, sp. Woodcut, f. 4	Garn, E. of Arenig	- - -	A similar one in the Caradoc of Sweden.
Encrinite rings, abundant, and of several species.	Craig-y-glyn, near Llanrhaidr.	—	—
Graptolithus, sp.	Pont-Seiont, 1 Carnarvon; Glan-y-gors, 3 miles E. of Llanerchymedd.	—	—
Diplograpsus pristis. Pl. 11 A, fig. 1, d e; pl. 12, fig. 1.	Conway	S. Wales.	—
D. ramosus. Pl. 12, fig. 1; pl. 11 A. fig. 1, a.	Do.	- - -	Scotland.
D. teretiusculus. Pl. 11 A, fig. 3	Conway; Glan-y-gors, 3 miles E. of Llanerchymedd.	Pembrokeshire.	—
Didymograpsus Murchisonæ? Siluria, 2d ed., pl. 1, fig. 1	Carnedd-Dafydd; Pont Seiont, Carnarvon.	Pembrokeshire; Builth.	—
Ampyx mammillatus. Port. Geol. Rep., pl. 1 B, figs. 1, 2.	Garn, Arenig	- - -	Waterford.
Phacops apiculatus. Siluria, foss. 13, fig. 3.	1 mile N.W. of Llanerchymedd; Treiorwerth.	—	—
Asaphus tyrannus. Pl. 13, figs. 1-7	Craig-y-glyn	S. Wales.	—
Asaphus Powisii, Murch. Pl. 15	1 mile N.W. of Llanerchymedd; Treiorwerth.	—	—
Cybele, sp.	Arenig, S.E. side	S. Wales.	—
Trinucleus concentricus, var. *favus*. Pl. 13, fig. 9.	Craig-y-glyn	Do.	—
Calymene Blumenbachii, var. *cambrensis*. Pl. 17, figs. 13, 14.	Craig-y-glyn; 1 mile N.W. of Llanerchymedd; Treiorwerth.	S. Wales; Shropshire.	—
Æglina major. Decade 7, G. Surv. Pl. 10, f. 9.	Glan-y-gors, 3 miles S.E. of Llanerchymedd.	—	—
Siphonotreta micula. Siluria, 2d ed., foss. 10, fig. 17.	Conway	S. Wales.	—
Lingula, sp.	Glan-y-gors; 3 miles S.E. of Llanerchymedd.	—	—
Orthis vespertilio. Siluria, pl. 6, figs. 1-3.	Craig-y-glyn	S. Wales.	—
O. turgida. M'Coy, Pal. foss., pl. 1, figs. 20-24.	Do.	—	—
O. spiriferoides. Siluria, 2d ed., foss. 34, fig. 2.	Arenig, S. side	Shropshire.	—
O. Actoniæ. Pl. 21, figs. 1-8	Garn, Arenig	- - -	Wexford, in strata probably Llandeilo.

* *D. teretiusculus* is found at Gogofau, S. Wales, most probably in Llandeilo flags (Prof Ramsay, 1864).

Name and Reference.	NORTH WALES.	Other Llandeilo Localities. in Wales.	Remarks on other Localities.
O. calligramma, var. Pl. 22, f. 1 -	1 mile N.W. of Llanerchymedd; Treiorwerth; Tyn-twr, 4 miles S. of Llangefni.	—	—
—— sp., crenulated ribs, *O. striatula?*	Garn, and S. side of Arenig	- -	*O. striatula* Wexford.
O. elegantula, Dalm. Siluria, pl. 5, fig. 5.	Tyn-twr, 4 miles S. of Llangefni.	—	—
O. insularis. Siluria, 2d ed.; Eichw. Geol. Russ., ii., pl. 8, fig. 7.	Garn - - -	- - -	Plentiful in the Caradoc rocks.
O. biforata. Siluria, 2d ed. foss. 33, fig. 4.	S. side of Arenig -	S. Wales -	Wexford.
Strophomena tenuistriata. Siluria, pl. 5, fig. 15.	Fron-oleu, 3 miles E. of Llangefni.	—	—
Leptæna 5-costata. Siluria, foss. 34, fig. 3.	Garn, and S. side of Arenig	-	A Caradoc species.
Ctenodonta, sp. - - -	Garn.	—	—
Maclurea? rather a small species -	Conway* - - -	- - -	A true Llandeilo genus.
Bellerophon perturbatus. Woodcut 16.	Bangor - - -	S. Wales -	Peculiarly a Llandeilo species.
B. bilobatus. Siluria, p. 7, fig. 9 -	Garn - - -	Do.	
—— sp., fine lines of growth -	Do.		
Orthoceras, fragments - -	Do.		

It should be observed in reviewing this list, that supposing these beds to be of the age of the Llandeilo flag, we have the genus *Ischadites*, which is almost certainly a regularly formed sponge, lower down than it has ever been before detected. Even in Caradoc rocks it is but rare.

Of the *Ampyx mammillatus* little can be said. It occurs in Waterford, among species which seem to be rightly referred by their discoverer, Major Austin, to the Llandeilo age; but in Sweden it is a Caradoc fossil. The *Trinucleus favus*, possibly a var. of the common trilobite *T. concentricus*, is only known in Llandeilo rocks, and the same is true of the variety termed *cambrensis* of the equally common *Calymene Blumenbachii*. Some would be disposed to regard this as a distinct species. There can be no objection to that view. *Asaphus tyrannus* is a well-known form peculiar to the deposit. *Æglina major*, *Diplograpsus ramosus*, *D. teretiusculus*, and *Siphonotreta micula*, are all Llandeilo forms.

Bellerophon perturbatus, I believe, very rarely indeed occurs in Caradoc rocks, but it is one of the commonest fossils in the Llandeilo flags. The Brachiopoda on the other hand have a wide range, and are all nearly common to the two deposits. They are the most widely distributed of all the Silurian forms, a fact in their history long known, and ably commented on, by Forbes, Sharpe, Suess, and other naturalists.

On the whole, I cannot doubt the existence of the Llandeilo flags all through North Wales, but Professor Ramsay's explanation of their local distribution, as the result of their unconformity to the rocks below, may receive additional value from the suggestion that they are also unconformably covered by the Caradoc strata; and that their occasional reappearance from beneath that formation, as at Conway and other places, may be in this way satisfactorily explained. I see no other mode of interpreting the facts. For I cannot doubt that the cliff of black slates at Conway, hemmed in closely by Caradoc and Wenlock rocks, is a fragment of the old formation; and if I be right in interpreting the *Maclurea*, it must be so.

CARADOC (or BALA) ROCKS.

The following lists contain all the species which have come under notice from the area now described.† It will be at once seen how rich a formation the Caradoc or Bala formation is in the North Welsh district. And by comparison

* Mr. Darbishire's collection, Manchester.

† I have included in it (with Prof. M'Coy's name attached to them) fossils mentioned only in the Cambridge Synopsis, such species having been chiefly collected by Prof. Sedgwick [illegible] myself in 1843 and 1844, and the localities being well known to me.

with other and well-known localities, the mollusca and crustacea of this district will be found, as above said, perfectly to agree over wide tracts of country.

The fauna is very different from that of the Llandeilo flags: *Graptolites*, so common in Llandeilo schists, are absent or nearly so in the coarse and sandy material of the Caradoc; and the trilobites are of different species or even of distinct genera. The Brachiopods only, which appear to be generally indifferent to the nature of the bottom, are identical. Still greater difference would appear, were we to compare the whole Caradoc fauna, here so rich, with other districts of the true Llandeilo age where fossils are also abundant. As the one formation is clearly superposed upon the other, and as every here and there the same mineral conditions recur in either formation, without much resemblance in their fossil contents, we are compelled to regard the considerable difference in the fauna as due chiefly to age.

This applies only in part to the Upper Llandeilo formation, which has several species identical with the Caradoc. The Lower Llandeilo (*see* p. 17) though frequently arenaceous, has but one fossil, the *Orthis calligramma*, in common with the lists here subjoined, and six graptolites.

It is to be remarked that the localities given for the more common species are only general ones. Our survey lists, derived from an immense collection made under the direction of the late Sir H. De la Beche, are crowded with localities,* of which it is only thought necessary to give the leading districts in which they are grouped, so as to show the range. For the less common fossils, all the separate localities are given.

LIST OF N. WELCH CARADOC FOSSILS.

Name.	Reference to other Works.	Locality.
Fucoids? pl. 14, f. 5, 6. -	- - -	*Merionethshire.*—Bala Lake.
AMORPHOZOA (*Sponges*).		
New sponge, spicula of -	- - -	*Montgomeryshire.*—Llanfyllin.
Stromatopora striatella, D'Orb.	Siluria, pl. 41, fig. 31.	*Montgomeryshire.*—Llanwddyn.
ZOOPHYTA.		
Favosites alveolaris, De Blainville.	Siluria, pl. 40, figs. 1, 2.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.* — Llanfyllin; Meifod; Llangedwyn. *Merionethshire.*—E. of Bala Lake.
F. Gothlandica, Linn. -	Ib., figs. 3, 4 -	*Denbighshire.*—S. of Llangollen.
Stenopora fibrosa, Goldf.	Ib., figs. 6, 7 -	*Caernarvonshire.* — Moel Siabod; Carnedd Dafydd; Penmachno; Llyn Idwal; E. of Y-Tryfan; Dolwyddelan. *Denbighshire.*—S.E. of Cerrig-y-Druidion; S. of Llangollen; Cyrn-y-brain, Wrexham. *Montgomeryshire.* — Llanwddyn; Welshpool; Meifod; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake; Corwen.
—— var.? *ramulosa*, Phill.	Phillips, in Mem. of Geol. Survey, vol. ii., pt. 1, p. 307.	*Denbighshire.*—S.E. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala.
S. Lycopodites, Say. -	Hall, Pal. N. York, vol. i., pl. 23, figs. 1–3.	*Caernarvonshire.*—Conway. *Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Meifod, &c. *Merionethshire.*—Bala.

* All these localities are accessible to students in the books of the Survey. It has been the labour of several years to determine them. And the new or unfigured species are many, as the unfilled generic lists will show.

Name.	Reference to other Works.	Locality.
Nebulipora favulosa, Phill. var. *lens*, M'Coy. Pl. 19, fig. 10.	- - -	*Caernarvonshire.* — Bettws-y-coed; Dolwyddelan. *Montgomeryshire.* — Welshpool; Meifod. *Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—E., W., and S.E. of Bala Lake; N. of Bala; W. of Corwen.
Chætetes petropolitanus, Pander.	Murchison's Russia, vol. ii., pl. A., fig. 10.	*Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—E. and W. of Bala Lake.
Heliolites interstincta, Wahl.	Siluria, pl. 39, fig. 2.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen. *Montgomeryshire.*—Llanfyllin.
H. megastoma, M'Coy, var. with prominent calices.	Siluria, p. 203, fig. 7.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Meifod. *Merionethshire.*—Bala.
H. tubulata, Lonsdale -	Siluria, pl. 39, fig. 3.	*Montgomeryshire.*—Allt-goch, Llanfyllin.
Petraia æquisulcata, M'Coy.	Pal. foss., pl. 1 B., figs. 23, 24.	*Denbighshire.* — Glyn Ceiriog (M'Coy). *Montgomeryshire.*—Llanfyllin.
P. uniserialis, M'Coy -	Ib., - -	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Meifod (M'Coy).
P. rugosa, Phill. -	Pal. foss., p. 7 -	*Montgomeryshire.*—Meifod (M'Coy).
P. subduplicata, M'Coy -	Siluria, p. 204, fig. 3.	*Denbighshire.* — Cyrn-y-brain; Wrexham; Glyn Ceiriog; S. of Llangollen.
Petraia, sp. - -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion; S. of Llangollen. *Merionethshire.*—S.E. of Bala Lake. *Montgomeryshire.*—Llanfyllin.
[*P. elongata*, Phill. -	Siluria, pl. 38, fig. 6.	*Merionethshire.* — Bala (M'Coy) very doubtful.]
Halysites catenularius, Linn.	Siluria, pl. 40, fig. 14.	*Denbighshire.*—S. of Llangollen. *Montgomeryshire.*—Meifod.
Omphyma turbinata Linn.?	Siluria, pl. 39, fig. 11	*Denbighshire.*—S. of Llangollen.
Cyathophyllum, sp. -	- - -	*Montgomeryshire.*—Llanfyllin.
Aulopora, large and small sp.	- - -	*Denbighshire.*—S.E. of Cerrig-y-Druidion.
ANNELIDA.		
Tentaculites anglicus, Salter.	Siluria, 2nd ed., pl. 1, fig. 3.	*Caernarvonshire.*—Pwllheli; Carnedd Dafydd. *Merionethshire* and *Montgomeryshire.*—Llanfyllin; Llanwddyn; E. and W. of Bala Lake. *Denbighshire.*—Glyn Ceiriog, S.E. of Cerrig-y-Druidion.
Cornulites serpularius, Schloth.	Ib., pl. 16, fig. 3, 10	*Caernarvonshire.*—E. of Y-Tryfan. *Denbighshire.*—S.E. of Cerrig-y-Druidion.
Serpulites longissimus, Murch.?	Ib., pl. 16, fig. 1 -	*Montgomeryshire.*—Llanwddyn, in the Berwyn Mountains.
Serpulites (cylindrical sp.)		*Merionethshire.*—E. and W. of Bala Lake.
Scolecoderma (see Appendix). Pl. 14, fig. 1–4.		[The tubes lie horizontally in the rock, and are slightly curved upwards.]
——sp., quite flattened -	- - -	*Merionethshire.*—W. of Bala Lake, N. of Bala.
——another sp. with cylindrical tubes (figs. 1-4)	- - -	*Merionethshire.*—W. of Bala Lake.
Scolites, worm burrows -	- - -	Everywhere in arenaceous rocks.

Name.	Reference to other Works.	Locality.
ECHINODERMATA.		
Cystidea.		
***Sphæronites** Litchi*, Forbes. Pl. 20, figs. 3, 4.	Mem. Geol. Survey, vol. ii., pt. 2, pp. 413–538.	*Merionethshire.*—W. of Bala Lake?
S. munitus, Forbes. Pl. 20, fig. 5.	- - -	*Do.* do.
S. pyriformis, Forbes. Pl. 20, fig. 1, 2.	- - -	*Do.* do.
S. punctatus, Forbes. Pl. 20, fig. 7.	- -	*Do.* do.
Sphæronites, two or three other species undescribed.	- - -	*Do.* do.
Echinosphærites balticus, Eichw. Pl. 20, fig. 10.	- - -	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—W. of Bala Lake.
E. (*Caryocystites*) *Davisii*, M'Coy. Pl. 20, fig. 9., *Caryocystites granatum*, Forbes, not of Wahlenberg.	Mem. Geol. Survey, vol. ii., pt. 2, pl. 21, fig. 4. - - -	*Caernarvonshire.* —Yspytty Evan (M'Coy). *Denbighshire.*—S. of Llangollen. *Merionethshire.*—W. of Bala Lake; Rhiwlas, Bala.
E. aurantium, Gyll.? Pl. 20, fig. 6.	- - -	These are introduced for comparison, but are only known in Pembrokeshire, S. Wales.
E. arachnoideus, Forbes. Pl. 20, fig. 8.	- - -	
Glyptocystites (n. genus, Billings), sp. undescribed.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Hemicosmites squamosus, Forbes.	Mem. Geol. Surv. vol. ii., pt. 1, pl. 20, fig. 1.	*Montgomeryshire.*—Near Llanfyllin.
H. pyriformis, V. Buch.? Pl. 20, fig. 12.	- - -	*Merionethshire.*—Rhiwlas, Bala.
H. oblongus, Pander. Pl. 20, fig. 11.	- - -	[Introduced for comparison]. In Pembrokeshire, S. Wales.
Pleurocystites; sp. (with rhombs, three on one side). For figure of genus, pl. 23, fig. 5.	- - -	*Merionethshire.*—Rhiwlas, Bala.
Undetermined genera of *Cystideæ*.	- -	*Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—N. and E. of Bala Lake.
Crinoidea.		
Glyptocrinus? basalis, M'Coy. Pl. 23, fig. 4.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. of Bala Lake. *Montgomeryshire.*—Meifod.
Heterocrinus, sp. -	- -	*Montgomeryshire.*—Meifod.
Asteroidea.		
Palæaster asperrimus, Salter. Pl. 23, fig. 2.	- - -	*Montgomeryshire.*—Quakers' Burial Ground, near Welshpool; Guilsfield.
P. obtusus, Forbes. Pl. 23, fig. 1.	- - -	*Merionethshire.*—W. of Bala Lake.
P. imbricatus, n. sp. Pl. 23, fig. 8.	- - -	*Montgomeryshire.*—Llanfyllin.
Edrioaster Buchii (*Agelacrinus*, Forbes). Pl. 20, fig. 13.	- - -	*Caernarvonshire.* — Near Yspytty Evan.
Protaster Salteri, Forbes. Pl. 23, fig. 3.	- - -	*Denbighshire.*—Cerri -y-Druidion.

Name.	Reference to other Works.	Locality.
CRUSTACEA (TRILOBITA).		
***Agnostus trinodus*, Salter.** Pl. 19, fig. 8.	- - -	*Merionethshire.*—W. of Bala Lake. *Denbighshire.* — S. and S.E. of Cerrig-y-Druidion.
***Agnostus*, sp.** - -	- - -	*Merionethshire.*—W. of Bala Lake.
***Acidaspis Brightii*, Murch.**	Siluria, Pl. 18, figs. 7, 8.	*Denbighshire.*—S. of Glyn Ceiriog (Woodw. Mus.).
***Ampyx tumidus*, Forbes.** Pl. 23, fig. 6. Woodcut 9.	- - -	*Montgomeryshire.*—Near Llangynnog (M'Coy). *Merionethshire.*—Rhiwlas, Bala.
***Asaphus Powisii*, Murch.** Pl. 15, figs. 1–5.	- - -	*Caernarvonshire.* — Dolwyddelan; Bettws-y-coed; Moel Siabod. *Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn; Meifod; N. of Llangedwyn; Llanfyllin; Welshpool. *Merionethshire.*—E. and W of Bala Lake.
***Asaphus radiatus*, Salter** (*Asaphus laticostatus*, M'Coy, not of Green), Pl. 23. f. 7.	Pal. foss. Woodw. Mus., pl. 1 E., fig. 18 only.	*Montgomeryshire.*—Llanfyllin. *Denbighshire.* — S. of Cerrig-y-Druidion.
***Calymene Blumenbachii*, Brong.** (*C. subdiademata*, M'Coy), chiefly if not wholly the var. *Caractaci*. Pl. 17, figs. 1–2	- - -	*Caernarvonshire.* — Near Pwllheli (M'Coy); Dolwyddelan. *Denbighshire.*—S. of Llangollen; S. of Cerrig-y-Druidion. *Merionethshire.*—E. of Bala Lake. *Montgomeryshire.*—Llanwddyn.
***C. senaria*, Conrad** (*brevicapitata*, Portl.) Pl. 17, figs. 8–12.	- - -	*Denbighshire.*—S.E. of Cerrig-y-Druidion; Cyrn-y-Brain; Nant-y-brain, Wrexham (M'Coy). *Merionethshire.*—E., W., and S.E. of Bala Lake, N. of Bala. *Montgomeryshire.*—N. of Llangedwyn; Llanfyllin; Llanwddyn; Meifod.
***Cheirurus bimucronatus*, Murch.** Pl. 18, figs. 4–7.	- - -	*Merionethshire.*—E. and W. of Bala Lake.
***C. juvenis*, Salter.** Pl. 18, figs. 1, 2.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N. and W. of Bala Lake, about Rhiwlas especially; Corwen (M'Coy). *Montgomeryshire.*—Llanfyllin.
***C. octolobatus*, M'Coy.** Pl. 18, fig. 3.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—Rhiwlas (M'Coy). [Also occurs in Ayrshire, Scotland].
***Cybele rugosa*, Portlock** -	Pal. foss. M'Coy, Pl. 1 G., fig. 8.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala Lake. *Montgomeryshire.*—Meifod (M'Coy).
***C. verrucosa*, Dalm.**	Ib., pl. 1 G., fig. 1–5.	*Caernarvonshire.*—Carnedd Dafydd. *Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn; Llanfyllin.
***Cybele*, sp.** - -	- - -	*Denbighshire.*—S. E. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin.
***Encrinurus sexcostatus*, Salt.** Pl. 19, figs. 5–7.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N. and W. of Bala Lake.

Name.	Reference to other Works.	Locality.
Homalonotus bisulcatus, Salter. Pl. 16, figs. 1-8.	- - -	*Caernarvonshire.*—Carnedd Dafyd; Pwllheli; Bettws-y-coed; Dolwyddelan. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Capel Garmon. *Montgomeryshire.*—N. of Llangedwin; Llanwddyn; Llanfyllin; Meifod. *Merionethshire.*—N. of Bala; E., W., and S.E. of Bala Lake.
H. rudis, Salter. Pl. 16, figs. 9-11.	- - -	*Denbighshire.*—Capel Garmon.
Illænus Bowmanni, Salter. Pl. 18, fig. 8.	- - -	*Denbighshire.*—S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin.
I. Davisii, Salter. Pl. 18, fig. 9.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—E.W. and N. of Bala Lake; W. of Corwen.
Lichas laxatus, M'Coy, Pl. 19, figs. 1-3.	- - -	*Denbighshire.*—S.E. of Cerrig-y-Druidion. *Merionethshire.*—E. and W. of Bala Lake. *Montgomeryshire.* — Llanfyllin; Llanwyddyn.
Lichas, sp. - -	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion.
Phacops alifrons, Salter -	Ib., pl. 1 G. fig. 12.	*Caernarvonshire.*—Penmachno hill (M'Coy). *Denbighshire.* — Capel Garmon (M'Coy). *Merionethshire.* — W. of Corwen (M'Coy). *Montgomeryshire.*—Meifod.
P. apiculatus, Salter -	Ib., figs. 17-19 -	*Caernarvonshire.*—Pwllheli. *Denbighshire.* — S. and S.E. of Cerrig-y-Druidion; Glyn Ceiriog (M'Coy); near Llangollen. *Montgomeryshire.* — Llanfyllin; Llanwddyn; Meifod. *Merionethshire.*—E. and W. of Bala Lake.
P. conophthalmus, Bœck.	Ib., fig. 22 (not 23)	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Glyn Ceiriog (M'Coy). *Montgomeryshire.* — Llanwddyn; Meifod.
P. macroura, Sjogren, (*truncatocaudatus*, M'Coy, not Portl.)	Pal. foss. t. 1 G., fig. [illegible]1.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen (M'Coy).
P. Brongniartii, Portl. -	Portl. Geol. Rep. Pl. 2, fig. 8.	*Merionethshire.*—W. of Bala Lake. *Montgomeryshire.* — Llanwddyn; Llanfyllin.
P. mucronatus, Brong. -	Brong. t. 3, fig. 9 -	*Merionethshire.*—W. of Bala Lake.
Remopleurides Colbii, Portl.	Decade 7, pl. 8, fig. 1.	*Do.* do.
R., new sp., allied to *R. radians*, Barr.	Barrande, pl. 43, fig. 33.	*Do.* do.
R. longispina, ? Portl.-	Portl. Geol. Rep.,	*Do.* do.
Remopleurides, large sp. -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Staurocephalus Murchisoni, Barr.	Barr. pl. 43, fig. 28	*Merionethshire.*—Rhiwlas; Bala.

Name.	Reference to other Works.	Locality.
Trinucleus concentricus, Eaton. Pl. 19, fig. 4.	- - -	*Caernarvonshire.*—Pwllheli (M'Coy); Conway; Carnedd Dafydd; Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.* Llangedwyn; Meifod; Llanfyllin; Llanwddyn (M'Coy). *Merionethshire.*—E. and W. of Bala Lake N. of Bala; Corwen; N. of Tremadoc (M'Coy).
T. seticornis, His. -	Leth. Suec. Supp. t. 40, fig. 19.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N.E. and W. of Bala Lake. *Montgomeryshire.*—Llanwddyn.
T. radiatus, Murch. -	Siluria, pl. 4, fig. 8	*Merionethshire.*—N. of Tremadoc (M'Coy).
Harpes Doranni, Portl. -	Portl. Geol. Rep., pl. 5, fig. 4.	*Denbighshire.*—S. of Llangollen.
Harpes, sp. - -	- - -	*Merionethshire.*—E. of Bala Lake.
Phyllopoda and Ostracoda.		
Beyrichia complicata, Salter. Pl. 19, fig. 9.	- - -	*Caernarvonshire.*—Carnedd Dafyd; *Penmachno.* *Denbighshire.*—S.E. of Cerrig-y-Druidion; Llanfwrog, near Ruthin (M'Coy). *Montgomeryshire.* — Llangynnog; Llanwddyn. *Merionethshire.*—E. and W. of Bala Lake.
B. strangulata, Salter -	Pal. foss., M'Coy, t. 1 E., fig. 1.	*Denbighshire.* — S. of Cerrig-y-Druidion.
Beyrichia, sp. - -	- - -	*Merionethshire.*—W. of Bala Lake.
Cythere? umbonata, Salter (*Ceratiocaris*, M'Coy).	Ib., fig. 6 - -	*Caernarvonshire.* Conway Falls (M'Coy); Dolwyddelan. *Denbighshire.*—Dermydd fawr, under Craig Bronbanog (M'Coy); Llanfwrog, near Ruthin. *Montgomeryshire.* — Llanwddyn; Llanfyllin; Meifod. *Merionethshire.*—E., W., and S.E. of Bala Lake; N. of Bala.
Polyzoa. (*Bryozoa.*)		
Diplograpsus pristis, His. Pl. 11 A., fig. 1 *d. e.* Pl. 12, fig. 1.	- - -	*Merionethshire.*—N. of Bala Lake. *Caernarvonshire.* — Conway falls, (M'Coy). *Denbighshire.* — Glyn Ceiriog, (M'Coy).
D. foliaceus, Murch. -	Siluria, pl. 1, fig. 2	*Merionethshire.*—Corwen (M'Coy); Pentre-cwm-dda, S. of Glyn Diffwys.
Graptolithus priodon, Bronn.	Ib., pl. 12, fig. 1 -	*Denbighshire.*—Nantyr, in Glyn Ceiriog (M'Coy). *Montgomeryshire.*—Peniarth; Meifod (M'Coy).
G. sagittarius, Linn. Pl. 11 A., fig. 2.	- - -	*Merionethshire.*—N. of Tremadoc.

Name.	Reference to other Works.	Locality.
Fenestella subantiqua, D'Orb.	Siluria, pl. 41, fig. 16.	*Denbighshire.* — S.E. of Cerrig-y-Druidion.
F. Milleri, D'Orb. -	Siluria, foss. 49, fig. 4, p. 239.	*Denbighshire.*—S. of Glyn Ceiriog (M'Coy).
	- - -	*Merionethshire.* — Cerrig-coedog, Corwen (M'Coy).
Fenestella, two species -	- - -	*Caernarvonshire.*—CarneddDafydd. *Merionethshire.*—S.E. of Bala Lake. *Montgomeryshire.*—Llanfyllin.
Phyllopora, two species, one with broad meshes.	- - -	*Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin.
P. Hisingeri (*Retepora*), M'Coy.	Pal. foss., pl. 1 C., fig. 18.	*Denbighshire.*—Glyn Ceiriog, near Chirk; near Wrexham.
Ptilodictya dichotoma, Portl	Portl. Geol. Rep., pl. 21, fig. 3.	*Montgomeryshire.* — Llanfyllin; Meifod. *Merionethshire.*—W. of Bala Lake.
P. costellata, M'Coy -	Pal. foss. t. 1 C., fig. 15.	*Denbighshire.* — Glyn Ceiriog (M'Coy).
P. explanata, M'Coy -	Ib., t. 1 C., fig. 16	*Denbighshire.* — Near Llangollen; Glyn Ceiriog; Cyrn-y-brain; Wrexham (M'Coy). *Montgomeryshire.* — Llanfyllin (M'Coy).
P. fucoides, M'Coy -	Ib., fig. 14 -	*Merionethshire.*—E. of Bala Lake; Corwen (M'Coy).
P. acuta, Hall - -	Siluria, foss. 27, fig. 2.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen (M'Coy). *Montgomeryshire.* — Llechwedd-wyd; Llanfyllin (M'Coy).
Berenicea heterogyra, M'Coy.	Pal. foss. 1 C., fig. 17.	*Merionethshire.*—W. of Bala Lake.
Glauconome disticha, Goldf.	Siluria, pl. 41, fig. 12.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Llanfyllin.
BRACHIOPODA.		
Atrypa marginalis, Dalm.	Siluria, pl. 9, fig. 2	*Caernarvonshire.*—Yspytty Evan. *Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn. *Merionethshire.*—Bala.
Crania divaricata, M'Coy	Pal. foss. t. 1 H., figs. 1, 2.	*Denbighshire.*—S.E. of Cerrig-y-Druidion. *Merionethshire.* — Pont-y-Glyn Diffwys; Corwen; Bala Lake.
Discina subrotunda, Portl.	Portl. Geol. Rep., pl. 32, fig. 10.	*Montgomeryshire.*—Llanfyllin.
Discina, sp. - -	- - -	*Caernarvonshire.*—Carnedd Dafydd. *Montgomeryshire.*—Llanfyllin.
Leptæna sericea, Sow. -	Siluria, pl. 5, fig. 14.	*Caernarvonshire.*—CarneddDafydd; Bettws-y-coed; Dolwyddelan; Llyn Idwal. *Denbighshire.* — S. of Cerrig-y-Druidion; S. of Llangollen; Cricor Mawr; E. of Llanelidan (M'Coy); S. of Pont-y-Glyn Diffwys. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin; N. of Llangedwin. *Merionethshire.*—E., W., and S.E. of Bala Lake; N. of Bala; *et passim.*
L. quinquecostata, (*Orthis*) M'Coy.	Sil. foss. Ireland, pl. 3, fig. 8.	*Merionethshire.*—W. of Bala Lake.

Name.	Reference to other Works.	Locality.
Leptæna tenuicincta, M'Coy.	Pal. foss. Woodw., Mus. pl. 1 H. fig 40.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin; Meifod. *Merionethshire.*—W. and N. of Bala Lake, especially Rhiwlas.
L. scissa, MSS. -	a common species -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. and W. of Bala Lake.
L. transversalis, Dalm. -	Siluria, 2nd ed., pl. 9, fig. 17.	*Denbighshire.*—Glyn Ceiriog. *Merionethshire.*—Bala, &c.
— var. *undulata*, Salter (*Lept. quinquecostata*, M'Coy in part).	Pal. Foss., pl. 1 H., figs. 30, 31.	*Montgomeryshire.* — Allt-yr-Anker; Meifod; Llanfyllin.
Lingula ovata, M'Coy -	Pal. Foss., t. 1 L., fig. 6.	*Denbighshire.* — S. of Llangollen (*L. longissima*, M'Coy). *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—E. of Bala Lake; N. of Bala.
L. tenuigranulata, M'Coy	Siluria, p. 212, fig. 5.	*Montgomeryshire.* — Llanwddyn; Meifod.
Orthis Actoniæ, Sow. Pl. 21, figs. 1–8.	- - -	*Caernarvonshire.* — Bettws-y-coed, Penmachno. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Glyn Ceiriog. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin. *Merionethshire.*—E. and W. of Bala Lake; W. of Corwen.
O. biloba, Linn. -	Siluria, pl. 9, fig. 20.	*Denbighshire.* — Glyn Ceiriog (M'Coy).
O. alternata, Sow. (*retrorsistria*, M'Coy). Pl. 19, fig. 11–13	- - -	*Caernarvonshire.*—Penmachno. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Glyn Ceiriog; Pentre-cwm-dda; S. of Glyn diffwys. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn; N. of Llangedwyn; Llangynnog. *Merionethshire.*—E. and S.E. of Bala Lake; Pont-y-Glyn-Diffwys.
O. flabellulum, Sow. Pl. 21, figs. 9, 10.	- - -	*Caernarvonshire.*—Carnedd Dafydd; Llyn Idwal; Llyn Ogwen; Boduan, large and fine; Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Glyn Ceiriog. *Montgomeryshire.* — Llanwddyn; Meifod; N. of Llangedwin; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake; Llanrhaiadr; Snowdon.
O. Hirnantensis, M'Coy -	Pal. Foss., pl. 1 H., fig. 11.	*Merionethshire.* — Aber Hirnant; Maes-y-fallen; and Cwm Æthnen, E. of Bala.
O. biforata, Schlotheim -	Siluria, p. 211, fig. 1	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.*—S.E. of Cerrig-y-Druidion; S. of Llangollen. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn. *Merionethshire.*—W. of Bala Lake.
— var. *fissicostata*, M'Coy	Pal. Foss., p. 193 -	*Montgomeryshire.*—Meifod (M'Coy). *Merionethshire.*—Bala; Aber Hirnant (M'Coy).

Name.	Reference to other Works.	Locality.
Orthis calligramma, Dalm. Pl. 22.	- - -	*Caernarvonshire.*—Bettws-y-coed; Dolwyddelan; Yspytty Evan. *Denbighshire.*—S. of Llangollen; S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—E. of Bala Lake.
O. crispa, M'Coy -	Pal. Foss., pl. 1 H., fig. 43.	*Caernarvonshire.*—Bettws-y-coed. *Montgomeryshire.*-Llanfyllin; Meifod.
O. elegantula, Dalm. (including *O. parva*, Pander and M'Coy).	Siluria, pl. 5, fig. 5	*Caernarvonshire.* — Llyn Idwal; Moel Siabod; Carnedd Dafydd; Bettws-y-coed; Dolwyddelan. *Denbighshire.*—S. of Llangollen; S. and S.E. of Cerrig-y-Druidion; Llanfwrog, near Ruthin (M'Coy). *Montgomeryshire.*—N. of Llangedwyn; Meifod; Llanfyllin; Welshpool; Llanwddyn. *Merionethshire.*—S. of Llangollen; S. and S.E. of Cerrig-y-Druidion; Corwen; Llanrhaiadr; N. of Tremadoc (M'Coy).
O. insularis, Eichw. -	Geol. Russ., 11, pl. 8, fig. 7.	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Llanrhaiadr.
O. spiriferoides, M'Coy -	Siluria, p. 211, fig. 2.	*Caernarvonshire.* — Dolwyddelan; Pwllheli; Penmachno. *Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin; Welshpool. *Merionethshire.*—E., W., and S.E. of Bala Lake; Dinas Mowddwy; Llanrhaiadr.
O. porcata, M'Coy. Pl. 19, fig. 14.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.*—S. of Llangollen; Cyrn-y-brain, Wrexham; Glyn-Ceiriog. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—Near Corwen.
O. sagittifera, M'Coy -	Pal. Foss., Woodw. Mus., pl. 1 H., figs. 15–19.	*Merionethshire.*—Aber Hirnant; E. of Bala.
O. simplex, M'Coy -	Sil. Foss., Ireland, pl. 3, fig. 18.	*Merionethshire.*—W. of Bala Lake.
O. testudinaria, Dalm. -	Siluria, pl. 5, figs. 1, 2.	*Caernarvonshire.*—Bettws-y-coed; Boduan; Penmachno. *Denbighshire.*—S. of Llangollen. *Montgomeryshire.*—Llanfyllin; Meifod; Gaer-fawr; Welshpool. *Merionethshire.*—E. of Bala Lake.
O. turgida, M'Coy -	Pal. Foss., Wood. Mus., pl. 1 H., figs. 21, 24.	*Caernarvonshire* — Dolwyddelan; Conway falls; Bettws-y-coed. *Denbighshire,*—Cerrig-y-Druidion. *Montgomeryshire.*—Llanfair.
O. vespertilio, Sow. -	Siluria, pl. 6, fig. 13	*Caernarvonshire.* — Dolwyddelan; Penmachno. *Denbighshire.*—S. of Llangollen; S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Meifod; Welshpool; N. of Llangedwyn; Llanwddyn; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake; near Corwen; Hirnant ridge.

Name.	Reference to other Works.	Locality.
O., sp. like *elegantula*	- - -	*Montgomeryshire.*—Llanfyllin.
Orthisina ascendens, Pander.	Pander, t. 17, fig. 6	*Denbighshire.* — Cyrn-y-brain, Wrexham. *Merionethshire.*—Corwen (M'Coy).
Rhynchonella, sp. (somewhat like *R. serrata* M'Coy), Siluria, p. 230, fig. 1.	- - -	*Caernarvonshire.*—E. of Y-Tryfan; Llyn Idwal; Carnedd Dafydd, (abundant, Salter).
R. depressa, Sow.	Siluria, pl. 22, fig. 17.	*Merionethshire.* — Brynbedwog; Bala (M'Coy).
R. (like *R. capax*, Hall)	- - -	*Merionethshire.*—W. of Bala Lake; Cymmerig; E. of Bala.
R., n. sp.	- - -	*Caernarvonshire.*—Carnedd Dafydd.
R., small plaited sp.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Siphonotreta micula, M'Coy	Pal. Foss., Woodw. Mus., pl. 1 H., fig. 3.	*Merionethshire.*—N. of Bala; near Glyn Diffwys (M'Coy).
Spirifer trapezoidalis, Dalm.	Siluria, pl. 9, fig. 24.	*Merionethshire.*—W. of Bala Lake.
Strophomena alternata, Conrad.	Pal. N. York, p. 102.	*Montgomeryshire.*—Llanfyllin.
S. antiquata, Sow.	Siluria, pl. 20, fig. 18	*Montgomeryshire.*—Llanfyllin.
S. depressa, Dalm.	Siluria, pl. 20, fig. 20.	*Caernarvonshire.*—Carnedd Dafydd; Llyn Idwal; Snowdon, &c.; Bettws-y-coed. *Denbighshire.*—S.E. of Cerrig-y-Druidion; S. of Llangollen. *Montgomeryshire.* — Llanfyllin; Llanwddyn; Meifod. *Merionethshire.*—E., W., and S.E. of Bala Lake, *et passim*.
S. deltoidea, Hall.	Hall, Pal. N. Y., vol. 1, t. 31A, f. 3.	*Denbighshire.*—Cerrig-y-Druidion; Cyrn-y-brain. *Merionethshire.*—Bala. *Montgomeryshire.*—Meifod (all the above localities from M'Coy).
S. expansa, Sow.	Siluria, pl. 6, fig. 4	*Caernarvonshire.*—Carnedd Dafydd; Bettws-y-coed; Dolwyddelan; Pwllheli. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Llangollen. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn; Cader Dinmael. *Merionethshire.*—E., W., and S.E. of Bala Lake; Llanrhaiadr.
S. grandis, Sow.	Ib., figs. 6, 7	*Caernarvonshire.* — Dolwyddelan; Boduan. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Bala.
S. tenuistriata, Sow.	Ib., pl. 15, fig. 4	*Caernarvonshire.* — Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Cyrn-y-brain; S. of Llangollen. *Montgomeryshire.*—Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—N. and E. of Bala Lake.
S. simulans, M'Coy	Pal. Foss., t. 1 H., figs. 33–35.	*Denbighshire.*—Glyn Ceiriog; Llangollen. *Montgomeryshire.*—Gaer-fawr, &c. (M'Coy).
S. Pecten, Linn.	Siluria, p. 251, foss. 58, fig. 3.	*Denbighshire.*—Glyn Ceiriog; Llangollen (M'Coy).

Name.	Reference to other Works.	Locality.
LAMELLIBRANCHIATA.		
Ctenodonta obliqua, Portl.	Siluria, p. 213, fig. 6	*Merionethshire.*—W. of Bala Lake.
C. lævis, Sow. - -	Ib., pl. 7, fig. 3 -	*Caernarvonshire.*—Bettws-y-coed; Dolwyddelan.
C. varicosa, Salt. Woodcut 13, f. 1.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Montgomeryshire.*—Llanwddyn. *Merionethshire.*—E. and W. of Bala Lake; N. of Bala.
C., sp. - - -	- - -	*Caernarvonshire.*—Carnedd Dafydd; Dolwyddelan. *Montgomeryshire.* — Llanwddyn; Llanfyllin.
C. Edmondiiformis (*Arca*, M'Coy).	Pal. Foss., pl. 1 K., fig. 2.	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Bala; Aber Hirnant (from M'Coy).
Cucullella, sp. - -	- - -	*Caernarvonshire.*—Bettws-y-coed; Dolydd Ceiriog Waterfall, in the Berwyn Mountains.
New genus allied to *Ctenodonta*.	- - -	*Montgomeryshire.*—Meifod.
Modiolopsis obliqua, Sow.	Siluria, pl. 7, fig. 2	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. of Bala Lake.
M., sp. like *M. Nilssoni*	Hisinger -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. and W. of Bala Lake.
M., 4 sp. - -	- - -	*Caernarvonshire.*—Carnedd Dafydd; Bettws-y-coed. *Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—N. of Bala.
Pterinea pleuroptera, M'Coy.	Pal. Foss., pl. 1 I., fig. 12.	*Denbighshire.* — Cyrn-y-brain, (M'Coy).
P. lineata, M'Coy -	Ib., p. 261 - -	*Montgomeryshire.* — Moel Uchlas; (M'Coy).
P., other species of -	- - -	*Montgomeryshire.*—Llanfyllin, &c. *Merionethshire.*—W. of Bala Lake, &c.
Orthonota (*O. verisimilis*, MSS.), a large Solen-like-species.	Not yet figured -	*Montgomeryshire.* — Allt-y-gader, Llanfyllin (Mr. Prosser's collection).
O. postlineata, M'Coy	Pal. Foss., pl. 1 I., fig. 22.	*Merionethshire.*—E. of Bala Lake.
O., various sp. - -	- - -	*Caernarvonshire.*—Dolwyddelan. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—N. of Bala.
Palæarca bulla, Salter. Woodcut 13, fig. 3.	- - -	*Montgomeryshire.*—Meifod (also at Horderley, Shropshire).
P. obscura, id. Woodcut 13, fig. 2.	- - -	*Montgomeryshire.*—Meifod.
P. modiolaris, id. Woodcut 12, fig. 1.	- - -	*Merionethshire.*—Bala.
P., sp. Woodcut 12, fig. 2	- - -	*Do.* do.
P. quadrata, id. Woodcut 12, fig. 3.	- - -	*Do.* Bettws-y-coed.
P. Billingsii, id., Woodcut 12, fig. 4.	- - -	*Montgomeryshire.*
GASTEROPODA.		
Cyclonema crebristria, M'Coy. Woodcut 14, fig. 5.	- - -	*Caernarvonshire.*—Carnedd Dafydd. *Montgomeryshire.*—Llanfyllin; Meifod. *Merionethshire.*—E. and S.E. of Bala Lake; N. of Bala.
C., sp. - - -	- - -	*Montgomeryshire.*—Llanfyllin.

Name.	Reference to other Works.	Locality.
***Holopea concinna*, M'Coy**	Siluria, p. 215, fig. 5.	*Denbighshire.*—S.E. of Cerrig-y-Druidion. *Merionethshire.*—N. of Bala.
***H. striatella*, Sow.** -	Ib., pl. 7, fig. 4 -	*Merionethshire.*—W. of Bala Lake.
***H.*, sp.** - - -	- - -	*Caernarvonshire.*—Bettws-y-coed.
***H. lymnæoides*, Forbes. Woodcut 14, fig. 3.**	- - -	*Merionethshire.*—Rhiwlas.
***H. exserta*, id. Ib., fig. 1**	- - -	*Merionethshire.*—W. of Bala Lake.
***H. carinata*, id. Ib., fig. 4**	- - -	Do. do.
***H. conica*, id. Ib., fig. 2**	- - -	Do. do.
***Holopella conica*, Sow.? or an allied sp.**	Siluria, pl. 34, fig. 10.	*Merionethshire.*—W. of Bala Lake.
***Murchisonia angulata*, Sow.**	Siluria, pl. 10, fig. 12.	*Caernarvonshire.*—Carnedd Dafydd.
***M. gyrogonia*, M'Coy** -	Pal. Foss., t. 1 K., fig. 43.	*Caernarvonshire.*—Yspytty Evan. *Montgomeryshire.*—N. of Llangedwin; Llanfechan (M'Coy).
***M. scalaris*, Salter** -	Quart. Geol. Journ., vol. 5, tab. 1, f. 2.	*Caernarvonshire.*—Carnedd Dafydd; Llyn Idwal.
***M. simplex*, M'Coy** -	Pal. Foss., pl. 1 L., fig. 21.	*Caernarvonshire.*—Bettws-y-coed; Moel Siabod. *Denbighshire.*—S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—N. of Llangedwyn; Llanwddyn; Meifod. *Merionethshire.*—W. of Bala Lake.
***M. cancellatula*, M'Coy** -	Pal. Foss., t. 1 L., fig. 20.	*Montgomeryshire.*—Allt-yr-Anker, Meifod (M'Coy).
***M. pulchra*, M'Coy** -	Sil. Foss. Ireland, pl. 1, fig. 19.	*Montgomeryshire.*—Allt-yr-Anker, Meifod (M'Coy). *Merionethshire.*—N. of Tremadoc (M'Coy).
***M. turrita*, Portl. ?** -	Geol. Rep., pl. 30, fig. 7.	*Merionethshire.*—Bala (M'Coy).
***M.*, sp.** - - -	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—W. of Bala Lake.
***Euomphalus*, sp.** -	- - -	*Merionethshire.*—W. of Bala Lake.
***Raphistoma lenticularis*, Sow. ?**	Siluria, pl. 10, fig. 10.	*Caernarvonshire.*—Carnedd Dafydd; Llyn-Idwal. *Montgomeryshire.*—Meifod.
***R. æqualis*, Salt. (*Euomph. qualteriatus*, id. *olim.*)**	Ib., p. 215, fig. 2 -	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—W. of Bala Lake.
***R.*, 2 species** - -	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—W. of Bala Lake. *Denbighshire.*—S. of Llangollen.
***Trochonema*, large sp.** -	- - -	*Denbighshire.*—S. of Llangollen.
PTEROPODA.		
***Theca triangularis*, Portl.**	Siluria, p. 218, fig. 2.	*Denbighshire.*—S. of Cerrig-y-Druidion.
—— ***reversa*, Salter. Woodcut 14, fig. 6.**	- - -	*Merionethshire.*—W. of Bala Lake.
HETEROPODA.		
***Bellerophon bilobatus*, Sow.**	Siluria, pl. 7, fig. 7	*Caernarvonshire.*—Bettws-y-coed; Dolwyddelan; Yspytty Evan. *Denbighshire.*—S. of Llangollen. *Montgomeryshire.*—Llangedwyn; Meifod. *Merionethshire.*—Dinas Mowddwy; E. and W. of Bala Lake.
***B. perturbatus*, Sow. Woodcut 16.**	- - -	*Caernarvonshire.*—Carnedd Dafydd.

Name.	Reference to other Works.	Locality.
Bellerophon carinatus, Sow.	Siluria, pl. 34, fig. 8	*Denbighshire.*—S.E. of Cerrig-y-druidion. *Montgomeryshire.*—N. of Llangedwyn; E. of the Berwyns. *Caernarvonshire.*—Twll-du, at the head of Llyn Idwal.
B. dilatatus, Sow. -	Ib., pl. 25, figs. 5, 6	*Denbighshire.*—S.E. of Cerrig-y-Druidion.
B. nodosus, Salt. Woodcut, fig. 15.	- - -	*Caernarvonshire.*—Llyn Idwal; Dolwyddelan. *Denbighshire.*—Teirw River, S. of Llangollen. *Montgomeryshire.* — Llanwddyn; Llangedwyn. *Merionethshire.*—E. and W. of Bala Lake; N. of Bala.
CEPHALOPODA.		
Cyrtoceras inæquiseptum, Portl.	Siluria, p. 220, fig. 1.	*Denbighshire.*—S. of Llangollen.
C. sonax, n. sp. Pl. 25, fig. 1.	- - -	*Merionethshire.*—Rhiwlas.
C. atramentarium, n. sp. Pl. 25, figs. 2–4.	- - -	*Merionethshire.*—W. of Bala Lake.
C., other species -	- - -	*Caernarvonshire.*—Carnedd Dafydd. *Merionethshire.*—Rhiwlas.
Lituites (*Trocholites*) *anguiformis*, Salt.	Pal. Foss., App., p. 8, pl. 1 L., fig. 26.	*Denbighshire.*—S. of Llangollen.
L. cornu-arietis, Sow. -	Siluria, pl. 7, fig. 10	*Merionethshire.*—W. of Bala Lake.
L. cornu-arietis, var. -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion (also in Tyrone).
L. planorbiformis, Conrad. Pl. 25, fig. 5.	- - -	*Caernarvonshire.*—Bettws-y-coed.
L., 2 other species, one with oblique waved septa.	- - -	*Merionethshire.*—Rhiwlas.
Orthoceras Ibex, Sow. -	Siluria, pl. 29, fig. 3	*Merionethshire.*—W. of Bala Lake.
O. vagans, Salt. Pl. 24, figs. 1–5.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—N. and W. of Bala Lake.
O. audax, n. sp. Pl. 24, fig. 7.	- - -	*Caernarvonshire.*—Moel Siabod. *Merionethshire.*—W. of Bala Lake.
O., sp. Pl. 24, fig. 6. -	- - -	*Do.* do.
O., smooth species -	- - -	*Caernarvonshire.*—Dolwyddelan. *Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala Lake; Rhiwlas, &c.
O., nearly smooth sp., but with fine longitudinal striæ.	- - -	*Merionethshire.*—W. of Bala Lake.

In examining this list, a few observations are worth making on the grouping of the fossils; for instance, the prevalence of one coral, the *Stenopora fibrosa*, the absence of *Graptolites*, and the presence of *Cystideæ* in notable quantity.

These last are confined (so far as I know) to the very remarkable patch of blue-grey argillaceous limestone at Rhiwlas Farm, and its neighbourhood on the north-west side of Bala Lake. Elsewhere the limestone has more or less of an arenaceous character, and it is the rarest thing for *Cystideæ* to occur in such a rock. But in the above-named locality they are found in plenty, and chiefly belong to two genera characteristic of Lower Silurian rocks, viz., *Sphæronites* and *Echinosphærites*. The former genus (pl. 20, figs. 1–5) is covered with pores in irregular order, arranged in pairs. The other, as well shown by Von Buch and

Forbes, is covered with numerous straight pore-canals, which striate with a web-like ornament the whole surface. *Hemicosmites* is a rarer form. The same groups of genera and species occur in similar beds, at one spot in South Wales, Shoal's Hook, near Haverfordwest, in Pembrokeshire.

The few starfishes quoted belong to genera now pretty well known to exist in Silurian strata. *Palæaster* is a common genus in the old rocks, but especially in the Caradoc. We have four species in England, and under the names *Palæaster* and *Stenaster* it is common in America. The other genus, *Protaster* (or *Tæniaster*,* for I cannot think the two genera sufficiently distinguished), is frequent in Upper Silurian. The one here figured is the first starfish found in strata of this age in Britain, and was discovered by Professor Sedgwick and myself in 1843, and named by Professor Forbes. The specimens were lost for years, but are now recovered from among Forbes's miscellanea, and both species are given in our plate.

Glyptocrinus basalis is one of the commonest of the crinoids of this formation; the scattered rings occur throughout the whole of the formation; they are very characteristic, and easily recognized by their hollow centre: there is no other determinable species,—though abundant fragments occur in the Bala limestone.

The worm tubes figured in plate 14 are interesting only as showing the position occupied by the great worms that made them. They lie horizontally in the beds, with both ends raised a little, the annelide has risen successively with the layers of deposit, one tube rising above the other, so as to form a rough index of the time taken to accumulate the stratum. Worm burrows are abundant everywhere.

The curious little bivalve crustacea named *Beyrichia* by M'Coy, are very abundant everywhere in Caradoc rocks, but are not strictly confined to them, occurring also in Llandeilo flags. *B. complicata* is the common form.

The Trilobites differ in species, as above said, according to the nature of the sea bottom. In the pale grey deep-water Bala limestone at Rhiwlas, Bala, we find—

Trinucleus seticornis, Hisinger.
Ampyx tumidus, Forbes.
Illænus Davisii, Salter.
Agnostus trinodus, Id.
Cheirurus bimucronatus, Murch. *C. octolobatus*, M'Coy.
Asaphus radiatus, Salter.

With many others.

In the sandstone beds above and below, and in the actual Bala limestone, where it is of a sandy character, we have—

Trinucleus concentricus, Eaton.
Illænus Bowmanni, Salter.
Asaphus Powisii, Murchison.
Calymene Blumenbachii, var. *brevicapitata*, Portl.
Phacops apiculatus, Salter.

And this arrangement appears constant, for in other localities remote from Bala, where the same conditions of depth and bottom appear to have prevailed, the limestone species occur in *calcareous* slate, and the common sand-loving species are absent. Where the conditions are reversed, the fauna alters once more. It is so with the Brachiopoda. In the argillaceous limestone *Leptæna 5-costata* is plentiful; in the sandstone *L. sericea*. *Strophomena expansa* is the universal fossil where sand has prevailed; it is not found in limestone—*S. alternata* takes its place. *Strophomena tenuistriata* is a sparsely distributed fossil everywhere; *S. depressa* very common in beds of all characters. *Orthis vespertilio* affects sandy limestone, and with *O. Actoniæ* and *O. biforata* appears not to have flourished well in other matrices; but *O. calligramma*, though able to live upon most deposits, appears to have had a special liking for coarse sand

* Billings, in his excellent Canadian Decades, No. IV. *Arthraster* of the same work appears to me to be a *Palæaster*.

and conglomerates, where it often grew to a large size, excluding other species. A due admixture of sand and calcareous matter, however, appears to have invited nearly all the species, which then grew in the greatest numbers and of the largest size. One of the best localities to study the arrangement of the Brachiopoda is the precipitous ground round Lake Ogwen. The map shows several beds of trap. Between these we have beds, with specimens of *Leptæna sericea* an inch wide! and of *Orthis elegantula* fully half an inch in diameter. The *Leptæna 5-costata* and *L. tenuicincta*, I never saw except in calcareous or argillaceous beds; and these are common but rather small shells, not generally known. *Lingula* is not common. One species, *L. ovata*, seems to be peculiar to the Bala limestone. Further eastward, one of the largest *Lingulæ* known is plentiful on the same horizon, *L. tenuigranulata*, M'Coy.

Of the Lamellibranchs but little can be said, for so many imperfect specimens remain to be some day described; and these are of species or genera identical with those of foreign Caradoc strata,—the genera *Orthonota*, *Palæarca* (Hall), and *Modiolopsis*, with a few *Pterineæ*, being the principal forms. *Ctenodonta varicosa*, a small triangular nuculoid shell, seems to occur in great plenty at various spots, *e.g.*, near Conway Falls, and along the line of hills west of Bala Lake. The *Ambonychia costata* of Conrad is one of the many species which help to link the British and American Caradoc rocks together.

Murchisonia, *Raphistoma*, *Holopella*, and *Holopea* are the common univalve shells. Of the last, three or four species occur in a group together in the Bala limestone at Rhiwlas. Their names have long been in MSS. by Forbes, and they are here figured for the first time. Perhaps the *Cyclonema crebristria*, M'Coy, is the most common univalve of all, and it is one which occasionally ranges up into the Llandovery rocks.

Of the Pteropod group, we have a very common fossil, *Theca reversa* (woodcut 14), which differs from Upper Silurian forms in having the opposite side convex to that which is usually so in the genus. It appears to be an equally common species on the other side of the Atlantic. *Pterotheca* (woodcut 18) is a much rarer form; it is wider and more expanded than any living shell of the group, and unlike Pteropods in general. We have an unfigured species, *P. undulata*, which occurs in tolerable plenty in the yellowish shaly beds in Caernarvonshire. It is a most singular fossil. But both the Pteropodous and Heteropodous orders of the group appear to have had larger, heavier-shelled, and altogether more extraordinary forms among them in Silurian times than they have ever had since.

Lastly, among the Cephalopods are some large and curious forms of *Cyrtoceras*. This genus, or collection of genera (for probably many distinct groups are included under this name), is remarkable for the variety of positions in which its siphuncle is placed,—sometimes on the dorsal, sometimes the ventral margin, and in every conceivable position between these two points.*

The small *Lituites* or *Trocholites planorbiformis* of our list is in the Woodwardian collection. It is not the only lituite-formed shell, for the *L. cornu-arietis* occurs with it near Bala. But the group is singularly rare in the Welch district, though so common both in Sweden and America.

These genera are only found at Rhiwlas, Bala, in the argillaceous limestone before noted; and the common *Orthoceratite* with them is the *O. vagans* (Salter), a species of wide distribution, since it ranges at least as far as Portugal. It abounds in the Bala limestone in one or two localities. (*See* plates 24 and 25.)

In this same limestone, when we were all collecting there, with Sir H. De la Beche and Professor Forbes, some curious phosphatic nodules were obtained, which were analysed by Dr. Playfair, and found to contain over 30 per cent. of phosphate.† Mr. Sterry Hunt had not at that time printed his valuable observations on the phosphates derived from molluscous remains in the still older

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* It would be an excellent type for a disciple of Darwin to start from, for the position of the siphon in the two great groups *Nautilidæ* and *Ammonitidæ* is remarkably constant, while *Cyrtoceras*, occurring as it does in older rocks than either, seems to combine both types. In *Orthoceras* it is variable, but not much so in any of the involute genera.

† Quart. Journ. Geol. Soc., vol. 7, 1851.

beds of Canada. It was at the time thought probable that fish had left their coprolite exuviæ in this locality; but the progress of research has shown that every one of the supposed fish remains in this or any other country, on a lower horizon than that of the Ludlow rocks, may be referred properly to other and inferior classes of animals.*

LOWER LLANDOVERY ROCKS.

As described in the Memoir, certain sandstones and conglomerates of this age, not separated from the Lower Silurian rocks at the time the maps were made, range into the district. They are but ill represented, however, in cabinets of fossils, and, except in the Meifod and Welshpool districts, have not been noticed in the Memoirs of Professor Sedgwick. The chief locality for these strata is the limestone and conglomerate described by him (as Bala beds, however, not as of Llandovery age) at Pen-y-craig and Mathyrafal, on the banks of the Vyrnwy, south-west of Meifod.† But the Rev. Dr. Cumming has also brought fossils from the ridges below Guilsfield, near Welshpool, which truly belong to this age.‡ The *Cefn*, 3 miles north-east of Welshpool, near Buttington, has a small patch of these rocks coloured Lower Silurian; and they occur among the Breidden Hills, as I learned from the investigations of Forbes, who did not, however, bring fossils home. It may here be said for those species quoted in our foot-note, from the two localities, Cyrn-y-brain, W. of Wrexham, and Pwllheli, Caernarvonshire, that the Geological Survey is not responsible for the localities, nor Professor M'Coy for the formations. The lists so carefully made out by him from Professor Sedgwick's collections accurately represent those collections. There is no reasonable doubt of the occurrence of Lower Llandovery fossils on the outlier of Cyrn-y-brain; but I must be allowed to suggest that it may well be doubted whether there be not some mistake as to the locality from which the so-called Pwllheli fossils were obtained. So far as we know, no patches of Middle Silurian occur all over the country west of the Snowdon chain, nor indeed for some distance east and south of it. On the other hand, if the *Pentameri*, and the Trilobites and shells quoted in the annexed list (taken from the Cambridge Synopsis), were really obtained from near Pwllheli,§ it is certain that the Llandovery rocks exist there.

It would be well worth any geologist's while who may take an interest in the subject, now that our maps are published, to search well the boundary rocks around the edge of the Wenlock formation. Should he not find these Llandovery beds, characterized by the numerous *Petraiæ* and *Pentameri*,‖ he will at least be working among the richest beds of the Caradoc formation, where the species are most abundant. A pale-coloured slate, which, when collecting with Professor Sedgwick, we used to term "pasty rock," and which ranges all through the Meifod and Llanfyllin country, might well be a portion of the Lower Llandovery series, as it is rich in corals. But the characteristic *Pentameri* were never found in it by us, nor, so far as I can learn, by other observers.

The list of species is as follows; and I have included all those quoted by Professor M'Coy, as the majority of the specimens were collected by myself in company with Professor Sedgwick. Professor M'Coy's name is attached to those I have not myself seen.

* *See* note by J. W. S. in Hugh Miller's 'Footprints of the Creator,' 2nd edit., by Mrs. Miller, p. 315.

† Quart. Journ. Geol. Soc., 1845, vol. i., p. 20. Quoted also by Prof. Ramsay, vol. ix., p. 179.

‡ It is probable that the Lower Llandovery beds sweep round the edge of the Wenlock rocks in many places. We can, however, only give known localities for fossils.

§ The species in question are:

Encrinurus punctatus - - -	All from Pwllheli, Cærnarvonshire, according to the Cambridge Synopsis.
Rhynchonella 10-*plicata* (*diodonta*, M'Coy)	
R. hemisphærica - - -	
Rhynchonella Upsilon - - -	
Pentamerus lævis - - -	
Strophomena compressa - - -	

These are all mentioned by M'Coy, and are certainly Llandovery species. The Cyrn-y-brain species are inserted in the general list, p. 38.

‖ The genus *Nidulites* should be looked for, *see* Siluria, 2nd edit., p. 203, Foss. 27, fig. 3. It is a common and characteristic Lower Llandovery fossil.

List of LOWER LLANDOVERY FOSSILS.

Name.	Locality.
Petraia uniserialis, M'Coy	Pen-y-craig, Llangynyw (M'Coy); Mathyrafal; Meifod; Cefn, near Buttington.
Petraia subduplicata, M'Coy	Cefn, near Buttington.
Stenopora fibrosa, Goldfuss.	Mathyrafal; Quakers' Burying Ground.
Heliolites megastoma, M'Coy	Do. (M'Coy).
H. interstincta, id.	Do.
Favosites alveolaris, Goldfuss.	Mathyrafal; Pen-y-craig, Llangynyw (M'Coy); Cefn, near Buttington.
Halysites catenularius, Linn.	Cefn, near Buttington; Mathyrafal (M'Coy); Pen-y-craig, near Llangynyw.
Omphyma turbinata, Linn.	Mathyrafal; Cefn, near Buttington.
Trinucleus concentricus, Eaton	Pen-y-craig, Llangynyw (M'Coy).
Calymene Blumenbachii, Brong.	Cefn, near Buttington.
— *var. Caractaci*	Mathyrafal (M'Coy).
Encrinurus punctatus, Brünn.	Mathyrafal.
Beyrichia complicata, Salter	Do.
Ptilodictya costellata, M'Coy	Do.
P. explanata, M'Coy	Mathyrafal; Pen-y-craig, Llangynyw.
P. lanceolata, Lons.	Pen-y-craig, Llangynyw.
Fenestella subantiqua, D'Orb.	Mathyrafal.
Graptolithes priodon, Bronn.	Pen-y-craig, Llangynyw; Cefn Grugos, W. of Llanfyllin.
Leptæna transversalis, Dalm., var. *undulata*	Mathyrafal; Pen-y-craig, Llangynyw.
L. sericea, Sow.	Mathyrafal (M'Coy).
Rhynchonella Lewisii, Dav.	Mathyrafal.
R. subundata, M'Coy	Mathyrafal and Pen-y-craig (M'Coy).
Atrypa reticularis, Linn., and *A. marginalis*, Dalm.	Cefn, near Buttington; Quakers' Burying Ground; Mathyrafal.
Rhynchonella subundata, M'Coy	Pen-y-craig, Llangynyw.
Strophomena euglypha, Dalm.	Quakers' Burying Ground.
S. depressa, Dalm.	Quakers' Burying Ground; Cefn, near Buttington; Mathyrafal (M'Coy).
S. antiquata, Sow. β.	Mathyrafal; Pen-y-craig, Llangynyw.
S. grandis, Sow.	Mathyrafal (M'Coy).
S. expansa, Sow.	Do.
Orthis biforata, Schl.	Mathyrafal and Pen-y-craig.
O. turgida, M'Coy	Do.
O. Actoniæ, Sow.	Do.
O. hybrida, Sow.	Do.
O. elegantula, Dalm.	Do.
O. lata, Sow., var. *protensa*	Do.
O. insularis, Eichw.	Do.
Pentamerus undatus, Sow.	Quakers' Burying Ground; Mathyrafal.
P. globosus, Sow.	Pen-y-craig; near Meifod; Mathyrafal.
P. lens, Sow.	Cefn, near Buttington; Mathyrafal.
P. lævis, Sow. (young of *P. oblongus*)	Cefn, near Buttington; Cyrn-y-brain; Wrexham.
Spirifer plicatellus, Linn.	Quakers' Burying Ground.
Spirifera percrassa (*Atrypa?* Sil. Syst.)	Cyrn-y-brain; Mathyrafal.
Discina, sp.	Quakers' Burying Ground.

UPPER LLANDOVERY ROCKS (May Hill group, Sedgwick).
For notes on these, *see* end of Appendix.

WENLOCK SERIES.

This great formation, long ago described in detail for N. Wales by Prof. Sedgwick, covers up with a slight degree of unconformability the Lower Silurian series; and in the remarkable sandy character of its base it differs so widely from the typical Wenlock rocks of the Silurian region, that the fossil contents of the two regions may well be supposed to be different. Professor Sedgwick's paper shows that one of the commonest fossils along the range of Modwl Eithin in

Denbighshire, and the western slopes of the Berwyns, is the *Chonetes* (*Leptæna*) *lata* of the Silurian system. This is a fossil rarely found in Wenlock strata; it is characteristic of the sandy mudstones of the Upper Ludlow rocks, and here in these lowest Wenlock beds it is associated with the *Bellerophon trilobatus*, a fossil not less characteristic of the Uppermost Silurian sandstones (or "tilestones" of the Silurian system). This commingling of the Ludlow and Wenlock types, however, does not destroy the very considerable difference of facies between the fossils of the two series; it only modifies them. Again, not a single characteristic Lower Silurian species, nor even a Llandovery species, is mingled with these, as the following lists will show.

I have separated the fossils of the sandy strata about Llansannan and Llangollen, as a higher Wenlock group; but there is in truth but little variety in the fauna of the Wenlock rocks of North Wales, except where the respective conditions of black shales and coarse arenaceous grit prevail. In the former we find abundance of *Graptolites*, of thin-shelled *Orthoceratites*, with *Cardiola* and a very few Brachiopod shells. In the latter, Brachiopod and Gasteropod shells are abundant, and corals are not rare; but a *Graptolite* or an *Orthoceratite* is seldom met with. *Encrinites* are plentiful in both kinds of rock, and are not all of Dudley species.

Name.	Locality.
Favosites alveolaris, Blainv. - -	Llangynyw Rectory, Montgomeryshire; Craig-hir; Mwdwl Eithin; E. of Merchlin.
Stenopora fibrosa, Goldf. - -	Moel Seisiog; Mwdwl Eithin; E. of Merchlin, S. of Conway.
—— var. *ramulosa*, Phill. - -	E. of Merchlin.
Petraia subduplicata, M'Coy - -	Plas Madoc.
P. bina, Lonsd. (small) - - -	Moel Seisiog.
Syringopora, sp. with tubercles inside -	Do.
Encrinite stems - - -	Craig-hir.
Glyptocrinus, 4 sp. - - -	Mwdwl Eithin; Moel Seisiog; Plas Madoc.
Actinocrinus, stems only - - -	E. of Merchlin.
A. pulcher, Salter - - -	Oernant; Nant-glyn; Maes-tyddyn; Nant-gwrhwyd-uchaf.
Trails of *Annelides* - - -	Oernant.
Cornulites serpularius, Schl. - -	Plas Madoc.
Tentaculites, sp. - - - -	Do.
Calymene Blumenbachii, Brong. - -	Craig-hir; Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
Homalonotus, sp. - - -	Mwdwl Eithin.
Phacops Downingiæ, Murch., var. -	Mwdwl Eithin; Moel Seisiog; Plas Madoc; E. of Merchlin.
P. caudatus, Brong. - - -	Moel Seisiog; Plas Madoc.
P. Stokesii, Milne-Edw. - - -	Llangynyw Rectory (M'Coy).
Encrinurus punctatus, Brünn. - -	Mwdwl Eithin; Plas Madoc.
Beyrichia Klödeni, M'Coy - -	E. of Merchlin.
Graptolithus priodon, Bronn (*G. ludensis*)	Llanrwst; Llangynyw Rectory; Oernant; Nant Morfydd; Craig-ddu-allt; Nant Glyn; Maes Tyddyn; Gwyddelwern; Cefn-Grugos, W. of Llanfyllin.
G. sagittarius, Linn. ? - - -	Moel Seisiog (M'Coy).
Polyzoa - - - - -	Plas Madoc.
Atrypa reticularis, Linn. - -	Craig Hir; Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
Atrypa, sp. - - - - -	E. of Merchlin.
Leptæna lævigata, Sow. - - -	Gwyddelwern.
L. minima, Sow. - - - -	Gwyddelwern.
L., sp. - - - - - -	Plas Madoc.
L. transversalis, Dalm. - - -	Craig-hir; Mwdwl Eithin; Moel Seisiog; Plas Madoc.
Orthis elegantula, Dalm. - -	Craig Hir; Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.

Name.	Locality.
Orthis elegantula (var., with flatter ventral valve).	E. of Merchlin.
O., with simple plaits - - -	Do.
Rhynchonella borealis, Schl. ? - -	Do.
R. nucula, Sow. - - - -	Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
R. decemplicata, Sow. - - -	Mwdwl Eithin; Plas Madoc.
R. do. ? - - -	Plas Madoc.
R.,—two species - - -	Mwdwl Eithin; Plas Madoc.
R.,—very fine ribs - - -	Moel Seisiog.
Strophomena compressa, Sow. - -	Do. (M'Coy).
Spirifer trapezoidalis, Dalm. - -	Craig-hir; Plas Madoc.
S. elevatus, Dalm. - - -	Mwdwl Eithin; Plas Madoc; E. of Merchlin.
S. plicatellus, Linn. - - -	E. of Merchlin.
S. percrassa, M'Coy - - -	Moel Seisiog (M'Coy).
Retzia cuneata, Dalm. - - -	Plas Madoc.
Ctenodonta,—flat sp. - - -	Plas Madoc; Mwdwl Seisiog; Gwyddelwern.
C. levata, M'Coy, not of Hall - -	Plas Madoc.
C. (Arca) Edmondiiformis, M'Coy. -	Moel Seisiog; Llangynyw Rectory.
Cardiola interrupta, Sow. - -	Oernant; Maes Tyddyn; Llangynyw.
C., sp. - - - - - -	Maes Tyddyn.
Pterinea retroflexa ? or *P. rectangularis* -	Mwdwl Eithin.
Mytilus, small convex sp. - -	Maes Tyddyn.
M. Chemungensis ? Conrad. - -	Plas Madoc.
M. unguiculatus, Salt. - - -	Do.
Modiolopsis, sp. - - - -	Do.
Clidophorus ovalis, M'Coy - -	Do.
Euomphalus, like *E. carinatus*, Sow. -	Oernant.
E. (or *Platyschisma*) thin shell, not *Platy. helicites*.	Craig-hir.
Loxonema elegans, M'Coy - -	Do. (also at Vinnal Hill, Ludlow.)
Murchisonia Lloydii, Sow. - -	Do.
M.,—sp. (flat sides) - - -	Plas Madoc.
M.,—sp. (prominent whorls) - -	Do.
Holopella gregaria, Sow. - -	Do.
Acroculia Haliotis, Sow. - -	Moel Seisiog; Plas Madoc.
Bellerophon carinatus, Sow. - -	Plas Madoc.
B. trilobatus, Sow. - - -	Do.
B. expansus, Sow. ? - - -	Do.
B. subdecussatus, M'Coy - -	Llanrwst.
Orthoceras annulatum, Sow. - -	Craig-hir.
O. primævum, Forbes - - -	Nant glyn; Craig-hir.
O. angulatum, Wahl. - - -	Llangynyw Rectory (M'Coy).
O. subundulatum, Portl. - - -	Craig-hir; Maes Tyddyn; Moel Seisiog; Llangynyw Rectory; Craig-ddu-Allt.
O., sp. - - - - - -	Plas Madoc.
Phragmoceras nautileum, Sow. - -	Do.
Lituites articulatus, Sow. ? - -	Nant-glyn.

WENLOCK ROCKS, near Llansannan.

Beds above Denbighshire Grits.

Name.	Locality.
Stenopora fibrosa, Goldf., var. *incrustans*	Frid-y-fedwen; Mynydd-Tryfan; Fron Fawr.
S., var. *ramulosa*, Phill. - - -	Frid-y-fedwen; Mynydd-Tryfan; Cefn Barog; Fron-fawr.

Name.	Locality.
Heliolites interstinctus, Wahl. - -	Fron-fawr.
Petraia bina, Lonsd. - - -	Frid-y-fedwen.
P., sp. - - - - - -	Do.
Cushion-like coral - - -	Do.
Spongarium Edwardsii, Murch. - -	Dinas Bran ; Llangollen.
Encrinite stems - - - -	Frid-y-fedwen ; Mynydd Tryfan ; Cefn Barog ; Fron-fawr ; Bryn-mawr.
Serpulites dispar. Salt. - - -	Dinas Bran (M'Coy).
Cornulites serpularius, Schl. - -	Fron-fawr.
Tentaculites ornatus, Sow. - -	Frid-y-fedwen ; Mynydd t Tryfan ; Bryn-mawr.
Phacops caudatus, Brong. - -	Frid-y-fedwen ; Cefn Barog.
Beyrichia Klœdeni, M'Coy - -	Bryn-mawr ; Capel-y-rhiw ; Frid-y-fedwen ; Cefn Barog ; Fron-fawr.
Nodular var. of do. - - -	Capel-y-rhiw.
Cytheropsis, sp. - - - -	Mynydd Tryfan.
Escharina or *Berenicea* - - -	Frid-y-fedwen.
Graptolithus priodon, Bronn - -	Tyn-y-pwll ; R. Dee, S. of Llangollen (M'Coy).
Atrypa reticularis, Linn. - -	Frid-y-fedwen ; Mynydd Tryfan ; Fron-fawr ; Cefn Barog ; Bryn-mawr ; Moel Fodia ; (Mynydd-y-Gaer ; Llanefydd, M'Coy).
A., sp. - - - - - -	Frid-y-fedwen.
Chonetes lata, Von Buch. - -	Bryn-mawr ; Frydd-y-Fedwen ; Mynydd Tryfan ; Moel Fodig ; Cefn Barog ; Fron-fawr.
Orthis elegantula, Dalm. - - -	Bryn-mawr ; Capel-y-rhiw ; Moel Fodig ; Frid-y-fedwen ; Mynydd Tryfan ; Cefn Barog ; Fron-fawr ; R. Dee, S. of Llangollen ; Mynydd-y-gaer.
O. lunata, Sow. - - - -	Dinas Bran (M'Coy).
Rhynchonella didyma, Dalm. - -	Frid-y-fedwen.
R. Wilsoni, Sow. - - -	Bryn-mawr ; Mynydd Tryfan ; Capel-y-rhiw.
R. nucula, Sow. - - - -	Mynydd-y-Gaer ; Bryn-mawr ; Fron-fawr ; Moel Fodig ; Capel-y-rhiw ; Llangollen.
R. navicula, Sow. - - -	Cefn Barog ; Moel Fodig ; Dinas Bran ; Welshpool ; Mynydd-y-gaer ; Llanefydd.
R., plaited sp. - - - -	Frid-y-fedwen.
Spirifer elevatus, Dalm. - - -	Bryn-mawr ; Frid-y-fedwen ; Mynydd Tryfan ; Fron-fawr ; Moel Fodig.
S. crispus, Linn. - - -	Llangollen.
Leptæna lævigata, Sow. - - -	Mynydd-y-Gaer ; Llanefydd, near Ruthin ; Welshpool.
[*L. tenuicincta*, M'Coy - - -	Llyn Alwen (M'Coy).]*
L. minima, Sow. - - -	Bryn-mawr ; Mynydd Tryfan ; Capel-y-rhiw ; River Dee.
Strophomena euglypha, Dalm. - -	Frid-y-fedwen.
S. depressa, Dalm. - - -	Bryn-mawr ; Fridd-y-Fedwen ; Mynydd Tryfan ; Cefn-Barog ; Fron-fawr.
S. funiculata, M'Coy - - -	Moel Fodig.
S. filosa, Sow. - - - -	Bryn-mawr ; Capel-y-rhiw ; Mynydd Tryfan.
Ambonychia ? acuticostata, M'Coy -	Dinas Bran.
Goniophora cymbæformis, Sow. - -	Frid-y-fedwen.
Pterinea retroflexa, Wahl. - -	Fron-fawr ; Capel-y-rhiw ?
Avicula mira, Barr ? - - -	Moel Fodig.
Cardiola interrupta, Sow. - -	Capel-y-rhiw ; Mynydd Tryfan ; Bryn-mawr ; Yr Allt ; Welshpool ; Mynydd-y-gaer ; Llanefydd.

* I feel sure this is a mistake. It is a wholly Lower Silurian form.

Name.	Locality.
Cardiola striata? Sow.	Mynydd Tryfan.
C., n. sp.	Tyn-y-pwll; Mynydd Tryfan.
Cucullella coarctata, Phill.	Dinas Bran (M'Coy).
C. antiqua, Sow.	Mynydd Tryfan.
C., sp.	Fron-fawr.
Ctenodonta anglica, D'Orb.	Do.
C. levata, M'Coy, not Hall	Dinas Bran (M'Coy).
Cyclonema, with three keels	Bryn-mawr.
C., sp.	Frid-y-fedwen.
Murchisonia Lloydii, Sow.	Mynydd Tryfan.
M., 2 sp.	Frid-y-fedwen.
Holopella gracilior, M'Coy	Dinas Bran (M'Coy).
H., sp.	Mynydd Tryfan.
Loxonema sinuosa, Sow.	Frid-y-fedwen.
Euomphalus funatus, Sow.?	Do.
Bellerophon trilobatus, Sow.	Do.
B. carinatus, Sow.?	Do.
Theca Forbesii, Sharpe	Dinas Bran (M'Coy).
Orthoceras Sedgwicki, Forbes	Frid-y-fedwen.
O. perelegans, Salt.	Do.
O. primævum, Forbes	Capel-y-rhiw; Tyn-y-pwll.
O. subundulatum, Portl.	Do.
O. bullatum, Sow.	Llyn Alwen (M'Coy).
O. ventricosum, Sharpe	Bron Einion; Pen-y-big (M'Coy).
O. laqueatum, Hall	Dinas Bran (M'Coy).
O. tenuicinctum, Portl.	Do.
O. tracheale, Sow.	Do.
Lituites articulatus, Sow.	Welshpool (M'Coy).
Protaster Sedgwicki, Forbes	Dinas Bran.

No trace of the Ludlow rocks proper has been discovered in the N. Welsh region. It is not certain that they do not occur there. But as no definite physical or paleontological line can be drawn among the slates and grits of the Denbighshire series we must omit them.

The conglomerates which occasionally underlie the mountain limestone of Flintshire, according to Sedgwick's observations do not contain any fossils, and may be Lower Carboniferous rather than belong to the Old Red Sandstone.

I must now describe chiefly the new or more characteristic species of the district: but as the Cambrian fauna is so scanty, I take advantage of these pages to figure and describe the long-neglected *Oldhamia*. It is not yet known to occur in Wales, but its occurrence there may be almost certainly predicted. I searched for it in the Cambrian grits, near Bangor, in vain.

DESCRIPTION OF THE SPECIES.

Plantæ.

Rare as are all remains of true plants in Silurian rocks, we yet cannot doubt that the more calcareous Algæ would leave their traces behind them; while the merely cellular mass which forms the frond of ordinary sea-weeds could leave at most but a carbonaceous stain. It is probable, indeed, that many of the black slates so frequent in Lower Silurian rocks owe their colour, at least in part, to decomposed Algæ. It is certain that these must have existed, if only as the food for the humblest of marine animals. But we have scarcely any definite proof of their occurrence in British Silurian, though so often quoted under the name of Fucoids: a term, as I have elsewhere shown, which had better be expunged from our lists.

Oldhamia, Forbes.

The *Oldhamia* of the Cambrian rocks can scarcely be otherwise than a calcareous *coralline* (not a coral), and the best recent authorities agree with me in referring it provisionally to plants, and not to animals. Mr. Busk, no mean authority in this question, rejects it from the *Polyzoa*. There is no good evidence that it belongs, as Prof. Forbes and Dr. Kinahan thought it did, to the *Sertulariadæ*, and the Rev. Mr. Berkeley suggests *Acetabularia* as its most likely ally.

Moreover the structure, though obscurely jointed, shows no trace of definite cells, such as the Hydroid Polypes, or the Polyzoa would present. But great latitude in this respect may be allowed for sea plants of the Nullipore group; and I shall describe *Oldhamia* as one of these.

I do not doubt that the two species belong to different genera. Prof. Göppert in his Flora Silur. Dev. und Unter-Kohl divides them into *Oldhamia* and *Murchisonites*, comparing the *O. radiata* with the *Tirocoleum* of Cayenne, or more readily with the *Tolypothrix coactilis* of Jutland. He gives the characters of the genus thus,—abbreviated,

Oldhamia (*O. radiata*, Forbes).—Frond of tufted filaments, sessile, radiated, much branched. Branches [excentric?] close set, simple, dichotomous, or forked.

Murchisonites (*O. antiqua*, Forbes,) he defines as follows:—Frond with geniculate jointed flexuose stem, giving off at the angles secondary ramuli, united at their base into fan-shaped fronds, which are bifid, either from the base, middle, or apex, and compares it fairly enough with the living *Liagora ramellosa*, Kützing, a Teneriffe sea-weed.

These analogies seem all striking, and indicate close study. But in truth, *Oldhamia* must have had a calcareous structure to have been preserved at all, and the comparison with the *Acetabulariæ* seems the best under all the circumstances. Prof. Göppert does not seem to have perceived that the hard filaments must needs have been connected by a membrane, now quite destroyed; and that the fronds must have been sufficiently hard to impress the sandy deposits in which they are imbedded.

Prof. Kinahan's important paper on *Oldhamia* in the Transactions of the Royal Irish Academy, gives elaborate figures of the radiated species; but he laboured in vain to convince me of the presence of the vesicles he thought he saw. The cells being inflated, give a spurious appearance of such structure.

I prefer keeping such obscure fossils in a single genus, as first described; and as the characters of the species are those given above for the genera, I need not repeat them.

O. radiata, Forbes.

Pl. 26, figs. 4, 5; and variety, or new species, figs. 6, 7.

O. radiata, Göppert; Flora Silurisch. Devonisch. Unter-Kohl, Pl. 34, figs. 1, 2. For the synonyms and localities see p. 6, Baily, Geol. Mag. 1865, vol. ii., 395, f. 5.

O. radiata, var discreta, Kinahan, see p. 242.

O. antiqua, Forbes.
Pl. 26, figs. 1–3.

For synonyms and localities, see pp. 242–244. ***Murchisonites antiquus***, Göppert, l. c. Pl. 35, fig. 1. *O. antiqua*, Baily, Geol. Mag. 1865, l. c. f. 3, 4.
These fossils are as yet known only in the Wicklow mountains, the *O. antiqua* being the more rare; *O. radiata* is found in plenty at Bray Head.

Amorphozoa.

Ischadites antiquus, new sp.

Fig. 4.

A fragment merely, and hence not very easily compared with more perfect species. Yet as the rhomboid areolæ are very narrow, *i.e.*, the intersecting lines cross one another at an acute angle, the species may well be kept apart from the better known *I. Kœnigii* of the Ludlow and Wenlock strata. Moreover the longitudinal and transverse lines are very faint compared with the oblique ones. In the Upper Silurian species they are strong and deep.

It is not, I think, generally known that the genus occurs commonly in Lower Silurian rocks. A fine specimen, of a new and undescribed species, with strong projecting spines on the fibres of the areolæ, is found near Llangollen. And this specimen shows, what is seldom seen, the attaching root fibres, branched and divergent in the muddy matrix. Again, a fine *Ischadites* is found in the Caradoc limestones of Sweden.

Several species yet undescribed occur in the Woolhope and Wenlock shales of Malvern and Usk. In fact a mass of material has now accumulated for the illustration of the *Amorphozoa* of the Silurian rocks. We have some of the genera so beautifully illustrated by Römer in his "Silurian Fauna of Tennessee" (*Astylospongia*), with others more regular in form, which appear to be widely diffused in Europe and Asia (*Sphærospongia*). And there are many others, some with calcareous spicula of enormous comparative size.

Locality.—Upper Llandeilo; Garn, Arenig Mountain, lying immediately on the traps.

Zoophyta.

Nebulipora favulosa, Phill.

Mem. Geol. Surv., vol. ii., pt. 1., pl. 30., f. 3., (Llandeilo flags,) var. *β lens; Nebulipora lens*, M'Coy, Pal. foss. Woodw. Mus. pl. 1 c. f. 7 (Caradoc strata).

I have transferred the only figure we had engraved of this species to the Caradoc plate, because I believe the above varieties to be such, and not of specific value. The clusters of fertile cells are about the same size in both, but less regularly hexagonal in the only Llandeilo specimen we have. The intermediate cells are smaller, when compared with specimens of the same size from Caradoc beds,—and also less regularly hexagonal.

These differences may be enough to constitute a distinct species in the eyes of some naturalists, but I think they are mere varieties. The Caradoc form is at first simply lenticular, or rather plano-convex, but becomes in age highly convex, sometimes gibbous. It grows fully two inches wide.

Locality.—Common (the var. *β*) all through the Caradoc or Bala districts of Shropshire and Wales. The original species from near Llandeilo, S. Wales, in Upper Llandeilo.

Echinodermata.

Glyptocrinus? (Cœlocrinus, n. g.) basalis, M'Coy.

Pl. 23, fig. 4; 4 *a. b.*, pelvis; 4 *d.*, rings of stem; 4 *c.*, arms and fingers.

G basalis, M'Coy, Synopsis Woodw. Mus., pl. 1 D., fig. 4; Siluria, 2d. ed., Foss. 29, p. 206.

Better specimens than M'Coy possessed show clearly that this cannot be referred to *Glyptocrinus*, inasmuch as it has subradial or parabasal plates, as in *Rhodocrinus*. Mr. Billings has given diagrams of a species of the latter genus, (Decade 4, Canadian Survey, pl. 1), which would fit well generically with our fossil, but differs entirely in aspect and proportions. The genus *Thysanocrinus*, with which he considered his *Rhodocrini* identical (*see* his p. 27), may or may not be comparable with that genus. I have no means of judging. But *Thysanocrinus* is not safely identifiable with the present fossil, since it has but a small cup, with scarcely radiated plates, a minute pelvis (I almost doubt it to be more than the edges of the upper stem ring), and altogether a different aspect.

I should propose *Cœlocrinus* for this fine large fossil, had I not a very decided horror of multiplying generic groups in an overburdened family. We have gone now far enough in analysing the cup of the various crinoid genera; and the time is come for some good naturalist to show us what are and what are not essential characters in this portion, which is after all only the antambulacral surface, equivalent to the upper surface in starfish, where it is of little generic value.

At present we have no certain clue among the affinities of this complex group. Müller's divisions are excellent as far as they go, and the nomenclature of the parts established by De Koninck the most convenient of all. But we have too many genera.

I shall give M'Coy's diagnosis, with additions; and the formula for the genus *Cœlocrinus*, if genus it be, would stand thus:—

Stem, simple, round, hollow, the canal very large.
Basal plates, 5, large and distinct.
Subradial plates, 5, hexagonal.
Radial plates, 3 × 5.
Inter-radials on all sides, numerous.
Interbrachials, many.
Arms, of a single row of bones, 10.

Hall does not give the number of arms for *Thysanocrinus*, nor do his figures show it. *Rhodocrinus* has 20, *Glyptocrinus* at least 20, ours has certainly ten only, with a double row of plates richly feathered with long tentacles.

The stems of this species are very long, quite cylindrical, of numerous close-set rings alternately larger and smaller, and widely hollow within so as to leave a large central cavity. The cup is semipyriform, about 1½ inches long, strongly marked by 5 great radiating ridges forked half way up; the pelvic plates wider than high, and much thickened internally, the subradial plates (pelvic, M'Coy) hexagonal, slightly longer than the primary radials, these are 3 in number, marked by a strong ridge which forks at 60° in the upper one. Three secondary radials are ridged in like manner; the ridges strongest towards the edge of the cup. The inter-radials and interbrachials are numerous.

There is a curious character in the pelvic plates, when viewed on the inner surface (I cannot see a trace of it outside): each plate has a number, varying from three or four to more than a dozen, of minute sharp tubercles, which are in pairs, the pair being divided by a slender ridge. These tubercles indicate, of course, an equal number of sharp indentations on the cast, which are arranged along the edges, or at the angles of the plates, or more commonly still on either side of the faint radiating ridges. In the cast they strikingly resemble the surface pores of the *Sphæronites*, with which they may possibly have more to do than appears likely at first sight. They do not mark true perforations in the plates.

All the plates seem to have been thin, and show considerable variety in form from slight pressure. All are marked by thick radiating ridges, those on the radial plates being by far the strongest.

Professor M'Coy does not mention the arms, which (in fig. *c.*) are seen to be short and broad, very unequal in length, one arm at least being greatly longer than the rest;—the joints short, but apparently not in double rows, the plumes very long and made up of compressed joints. The number of arms is only 10, and they are unbranched.

The stem-rings are the most easily recognized portions of this fossil, which, in fragments, is as characteristic an one as can be named in the Caradoc series. Loose stem-rings of it, easily known by their wide central canal, are scattered over all the sandy slabs of slate near Bala Lake, and in the Berwyn Mountains. The perfect pelvis is not uncommon, especially near Meifod in Montgomeryshire.

Locality.—CARADOC rocks.—Everywhere in Wales. Figs. 4, 4*a.*, Guilsfield, near Meifod; fig. 6, near Llanwddyn, in Berwyn Mountains; figs. 4*c.*, 4*d.*, Bala.

Cyathocrinus,—sp.

Pl. 11 B., fig. 9.

A fragment, not half an inch long, composed of alternating joints, larger and smaller, and with a rounded outline. The section of the stem is pentagonal, or rather 5-parted, and the central canal very small.

It is the oldest crinoid known in the British rocks, and is clearly distinct from *Glyptocrinus,* the Caradoc fossil. The very small canal and angular stem would alone separate it. There are species of the genus *Cyathocrinus* with 5-angled stems, but the name must be considered rather as a family—than as a generic—one.

Locality.—LOWER LLANDEILO, W. of Stiper Stones, Shropshire.

CYSTIDEÆ, Von Buch.

Of all the species known of this curious tribe, none are so abundant as some of those which figure in our plate 20. First recognized as British fossils by M'Coy, who described a large and common Irish species from Wexford; the British *Cystideæ* received scientific arrangement, and a full discussion, at the hands of Forbes, in his excellent essay in the Memoirs of the Survey, vol. ii., pt. 2.

Von Buch and Volborth had previously described the Russian species, and established the main genera; and later than all, the clear synopsis by Joh. Müller, translated from the Berlin Transactions of 1853 by Huxley in 1854,* has rendered the arrangement and description of the *Cystideæ* an easier task than could previously have been supposed.

In truth the group, numerous as it is, and variable as the species are in form (and mode of preservation, an important item in the case), is very definite in character, and it is not now at all difficult to determine the genera, whatever may be thought of the claims of the several species.

Billings' discoveries in Canada have largely tended to illustrate the subject, and his work is admirable so far as it goes.† And the later volumes of Hall are full of good material.

The whole group is essentially in contrast with the contemporary but much longer-lived companion group, the *Crinoids.* With globular bodies, scarcely showing any oral surface, short inconspicuous stems, and for the most part rudimentary arms, which, indeed, seem to be sometimes absent altogether, or reduced to a few tentacles, the contradiction of character, in the *Cystideæ,* as compared with the long stems and plumose arms of the *Crinoids,* must strike even a casual observer. The rhombs and pores on the surface are hardly less remarkable characters, and in the form they assume peculiar to the group.

The pores are considered, whether concentrated in the peculiar rhombs, as in *Echinoencrinus;* covering the surface of all the calycine plates, with canals connecting them, as in *Echinosphærites;* or simply scattered in pairs over the

* Annals and Mag. Nat. Hist., 2nd series, vol. xiii., p. 212.
† Canadian Organic Remains, Decade 3, 1858.

surface, as *Sphæronites;* to be analogous to the respiratory pores of *Asterias,* and not to be passages in any sense for suctorial feet.

Müller's synopsis is as follows :—

I. *Cystideæ* with pore rhombs, *i.e.,* with the pores united by long canals, which extend from one plate to another, and are either—

  a. Universal over the calyx, but covered over by external calcareous plates; the pores, therefore, only being visible at the ends of the canals: Ex. *Hemicosmites, Caryocrinus.* (Upper and Lower Silurian.)

  b., c. Universal, but connected from plate to plate by single or double canals, open on the surface, and visible, therefore, between the pores which they connect. In some species the canals are single (*b*), or even one canal serves for a row of pores; in others (*c*) two or even three or four canals are supplied to a single pair of pores. *Echinosphærites, Caryocystites,* (which last genus seems to be only a subgenus of the former). (Lower Silurian.)

  d. Pores and canals restricted to special portions of the surface, hence the species possess only a few pore rhombs. *Echinoencrinus, Pseudocrinus, Apiocystites,* and several other genera. (Upper and Lower Silurian.)

II. *Cystideæ* with double pores (*Diploporitidæ*); the connected pairs being on the same, not different plates. *Sphæronites, Protocrinites, Glyptosphærites.* (Lower Silurian.)

III. *Cystideæ* without pores. *Cryptocrinites.* (Lower Silurian).

It is worthy of remark, that of all the genera, which are strictly Silurian, the only forms proper to the Lower Silurian are the two last, and those with universal pore-canals open over the surface. Of the others, those with covered pores are either Upper or Lower Silurian. And the genera with few pore rhombs, occur also in both formations, but more especially in Upper Silurian. We have figured, pl. 20, the British forms given in Forbes' Memoir, reproducing the principal figures from his plates. And on the same plate have inserted the *Edrioaster* (*Agelacrinites*) *Buchianus,* fig. 13., which he regarded as a *Cystidean,* but which Billings has shown to be nearly allied to the starfishes.

We will reverse the order of these groups, and begin with the truly Lower Silurian forms. (No *Cryptocrinites* are known in Britain.)

Sphæronites pyriformis, Forbes.

Pl. 20., f. 1, 2.

Caryocystites pyriformis, Forbes, Mem. Geol. Surv., vol. ii., pt. 2., pl. 21., f. 1.

The elongate, pouch-like form of this species easily distinguishes it from any other, and its pairs of pores are scattered evenly, but thinly, over the surface. The pores of each pair are also remote from each other, being separated by a prominent oval boss, encircled by a depressed line. When the surface is worn, this line becomes a raised border surrounding a slightly convex area. There is no furrow or depressed space to connect the pores, nor are they in any case sunk below the general surface, as in the two next species.

Locality.—Caradoc or Bala Limestone, Rhiwlas, Bala. Collected, as were all the other species in this locality, by Prof. Edward Forbes and Mr. R. Gibbs. (Mus. Pract. Geology.)

Sphæronites munitus, Forbes.

Caryocystites munitus, Forbes, l. c., pl. 21., f. 3.

A sub-globose, short, and rather minute species, not above half the size of the preceding, from which it further differs by the unevenly scattered pairs of pores. The pores of each pair are closer together, and set in oval depressions with a somewhat raised border.

Around the square mouth are four tubercles, which have their upper surfaces flattened, and may have borne arm joints. One of them especially is larger than the rest and more decidedly truncate. A thread-like ridge runs from one to the other of these bosses, and borders the mouth. The ovarian? aperture is very large. I do not see the six plates covering it, which Forbes has figured, and doubt them.

Locality.—Caradoc, Rhiwlas, Bala.

Sphæronites punctatus, Forbes.

Pl. 20., f. 7.

Sphæronites punctatus, Forbes, l. c., pl. 22., f. 2.

A large globular species, very common in the Bala limestone, but of which only enough is preserved to show the specific characters. It might possibly be a *Glyptosphærites*. The mouth was produced as in *S. pyriformis*, but the shape was much more globular, and apparently not attenuated at the base. The ovarian ?* (or anal) pyramid is very low and flat, and not divided visibly into any segments.

The pores are close set, very many on a plate, each pair linked together by a narrow and rather deep channel, with a slightly raised edge when the surface is perfect. When it is abraded, the pores alone show on the surface. Usually the straight short channels, huddled in irregular fashion over the plates, appear more like a rough sculpture than a structural arrangement. The pores appear, from one tolerable specimen, to be very rare near the base, and those of each pair are placed wider apart, with, of course, a longer channel connecting them.

Locality.—Caradoc, with the last, at Rhiwlas, Bala.

We also figure the following species from South Wales. They will assuredly be all found at Bala by a careful search.

Sphæronites Litchi, Forbes.

Pl. 20, f. 4. (3?).

Caryocystites Litchi, l. c. Pl. 21, f. 2.

There are two forms, and, I fear, two species, figured under this name in Forbes' paper, nor are the specimens quite good enough to show us the limits of the two species; our fig. 3 is one of these, a species with large plates, and numerous, but not closely set, scattered pores, irregularly placed, and seated in small oval excavations, with a slightly raised border, on the surface of plates which, though tolerably even, are sculptured and granulated; fig. 4 *c* also belongs to this species. It is common at Sholes Hook, Pembroke (*Caradoc*). But not being sufficiently figured here, I will not give it a name; indeed, I feel little doubt it is *S. munitus* in an older state. It has the oval tubercles and square mouth and scattered pores. Figs. 4, 4 *a*, 4 *b*, represent the true *S. Litchi*, in which the surface of the plates is thickly and evenly covered by areolæ, with raised thread-like borders separating them, and each bearing in its centre a ragged tubercle, which carries the pair of pores. It is the raised border of the pores highly exaggerated, and the reverse of the usual character in the genus, which has, on the whole, excavated channels for pores on an even surface. The pores of each pair are near together on the general surface of the body; but, nearer the mouth and its curious tubercles, the pores begin to elongate and crowd each other into a sort of radiate structure. In some specimens near the mouth this structure is so much shown as easily to suggest to the naturalist a passage to those genera, *Echinosphærites*, in which the elongation of the channels and the elevation of their borders is normal and constant. *S. Litchi* may be looked on as a transition species, and a pretty one it is. The resemblance to the tropical fruit *Litchi* is very close, but it required a botanist to see the analogy. Fig. 4 *b* is, as stated in the explanation of Forbes' plates, a magnified view of Fig. 4, and therefore it must be regarded in a reverse sense, the hollows being taken for elevations.

The curious epaulette-like tubercles, which border the mouth, are more developed in the *S. Litchi* than any other, and are deeply striated or ridged in a radiate direction from the mouth. I must figure these *Cystideæ* at some future opportunity, if better hands do not take them up; for much more is known of the group now than was known in Forbes' time, and his researches paved the whole way for it, in England at least.

Locality.—Sholes Hook (Caradoc).

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* I strongly suspect Mr. E. Billings is right: this is the anal, not the ovarian, pyramid.

Sphæronites stelluliferus, n. sp.

Pl. 20, fig. 6 (6 *a* wrongly figured).

S. aurantium, Forbes, Mem. Geol. Survey, vol. ii., pt. 2, Pl. 22, figs. 1 *a*, *b*, .

It was not a bad idea to put this species among the multiplied varieties of *E. aurantium*, for it really is allied to it; yet it differs in nearly all its characters. What is regarded (Forbes, *supra* fig. 1 *a*) as the base is really the epauletted apex, and assuredly the external ornament (here figured, 6 *a*) has been much exaggerated to suit the view taken of its affinities. It is far too much radiated; and I only give it in the hope of calling attention to the fact that the common northern species, *E. aurantium*, has never been found in Britain, unless the *Ech. granulatus* of M'Coy be, as Forbes suspected, the same species: it is very like it. *S. stelluliferus*, however, tends yet more closely than *S. Litchi* to unite the *Sphæronites* with the *Echinosphærites*. It has longer radii to the pairs of pores, and these are so arranged round the periphery of the plates, and extend usually so little into it, as to suggest the strongest analogy with the radiate surface-channels of *E. aurantium*. Moreover it occasionally happens, though rarely, that the linked pores are on opposite plates; while I have observed near the mouth of *Ech. aurantium* that the two ends of the pore channels are sometimes on the same plate. Further observation will doubtless increase the points of transition, which in nowise tend to destroy the value of the genera.

A sub-globular and rather smooth species, with large polygonal plates, covered loosely with linked pores in narrow linear oval sunk channels, which vary in length from twice or less their diameter to five or six times that proportion. They are not provided with raised borders, and are arranged radiate-fashion, chiefly near the edge of the plates, but in part irregularly, the radiate pattern being sometimes obscure.

The mouth is oval?, not produced, its edge simply thick and incurved, and round it are arranged five, not four, of the epaulette-like tubercles above described in *S. Litchi*. We had unfortunately figured the internal cast only before I found out it was a new species. The surface of the cast is covered with numerous projections (very like fig. 4 *c*), due to the numerous pairs of pores. As there are no traces of the pore-channels interiorly, there can, of course, be no radiate arrangement on the inner cast.

Fig. 6 *a* represents the outer surface, but, as above said, highly exaggerated as to the radiation. Nor is the central tubercle conspicuous, and I cannot help believing that Forbes had allowed his artist to figure a portion of the true foreign *Aurantium* to make up for deficiencies in the British specimens supposed identical. Such mingling of figures, however, must be condemned, as tending to create confusion. It is introduced here, to call attention to it, and prevent future mistakes.

Locality.—Sholes Hook (as above), CARADOC.

Echinospherites arachnoideus, Forbes.

Pl. 20, fig. 8.

Sphæronites, Forbes, l. c., Pl. 22, fig. 4.

This exquisite species is too well marked, and has been too fully described by Forbes, to need fresh illustration. The peculiar close striation is a good and striking character.

Locality.—CARADOC, Sholes Hook, Haverfordwest.

Echinosphærites Balthicus, Eichw.

Pl. 20., f. 10?

Sphæronites Balthicus, Forbes (also figured by Eichwald, Von Buch, Hisinger, &c.)

There is no doubt about this species, which is common in Pembrokeshire, but more rare at Bala. I keep it distinct for a while from the following, which, however, may be only a variety.

Locality.—CARADOC, S. Wales and N. Wales.

Echinosphærites Davisii, M'Coy.

Pl. 20., f. 9.

Caryocystites Davisii, Forbes, l. c. Pl. 21., f. 5. *C. granatum*, id. (not Wahl.) f. 4.

In the simplicity of its ridges, this fossil differs from the *E. Balthicus*, with which Prof. M'Coy seems to think it cannot be even compared. Judging from Westmoreland specimens, however, it is likely to be, as Forbes suggested, closely allied to that fossil, if not a variety of it. The main ridges have frequently one on each side of them, the remaining space being flat, while *E. Balthicus* has ridge within ridge to the middle of the triangle.

The pore-channels are only faintly marked as radiations round the plates. But the concentric lines are strong enough in all the specimens.

I think the true *E. granatum* must be a very different species, judging from the figures. But, as I have not seen it, I will not pursue this further. The two figured by Forbes will best agree with *E. Davisii*, McCoy.

Locality.—CARADOC, Rhiwlas, Bala; Coniston, Westmoreland.

Hemicosmites oblongus, Pander.

Pl. 20., f. 11.

Forbes, l. c., vol. ii., pt. 2., p. 511, pl. 20., f. 6. (*Echinosphærites oblongus* of Pander. Beitr, t. ii. (quoted as xi. by Forbes), f. 22, 23?

I think Forbes is right in referring to this figure by Pander, though he does so doubtfully. But the figure itself is so imperfect as to justify any amount of doubt, and by mistake the wrong plate is quoted.

Locality.—CARADOC slates of Sholes Hook, Haverfordwest.

H. rugatus, Forbes.

Pl. 20., f. 12.

H. pyriformis, Von Buch? Forbes, l. c., vol. ii., pt. 2., p. 511., pl. 20, f. 2–5., *H. rugatus*, id. in. vol. ii., pt. 1., p. 302. (*Echinosphærites malum*, Pander. Beitr. t. xxix. f. 1 *a*.)

It is to be wished that Forbes had retained his originally proposed name, *H. rugatus*, for surely there is little resemblance between Pander's smooth and only slightly ridged fossil, and this with strongly radiated plates.

Locality.—CARADOC, Sholes Hook, Pembrokeshire; Llanfyllin, Bala, N. Wales.

Pleurocystites Rugeri., n. sp.

Pl. 23, fig. 5.

Fragments of this genus occur in the Bala limestone itself, and also in beds of the same age in South Wales. But these are so imperfect, that instead of figuring them I shall give the outline of a perfect specimen from South Wales. It is only the internal cast, and shows the interior shape of the rhomb-bearing tubercles which ornament the surface, as well as the minute plates which cover one surface or side.

Our specimen shows a part only of one of the two long-jointed arms which are the characteristic mark of the genus; and for perfect figures I must refer to Billing's beautiful plates in the Decade of the Canadian Survey iii., pls. 1, 2. Our species differs from *P. squamosus*, Billings, the species most like it, in the broad base, short form, and highly ornamented plates. *P. filitextus*, which appears from his description to come nearest in sculpture, has large plates on the lower (or irregularly plated) side.

The pectinated rhombs of this fine broadly-triangular species are very prominent, and flat or even convex above. The upper ones lie transversely, and are three times as long as broad. The lower rhomb is closer upon the cordate base of the cup than in any other species, so that the central area of the upper surface is conspicuously large. The basal plates project over the stem considerably. The upper plates are very thick, and their outer margin angular; the surface with the usual 6 strong radii reaching from centre to centre, with fainter intermediate rays branching from these; the interspaces filled with tubercles arranged in more or less of a concentric fashion. The lower or squamate surface is rather large, irregularly bounded by the marginal plates, and covered with minute, convex, granular scales.

Locality.—CARADOC, Blaen-y-cwm, near Llandovery, S. Wales.

Asteriadæ.

Palæaster obtusus, Forbes.

Pl. 23, fig. 1.

Mem. Geol. Survey, Decade I., pl. 1, fig. 3; Salter, Annals and Mag. Nat. Hist., 2d ser., vol. 20, described.

P. uncialis, depresso-convexus, brachiis obtusis subconicis brevibus, [*insuper reticulato-spinosis*, Forbes]. *Ossicula adambulacralia maxima transversa, punctato-sculpta. Ambulacra angusta.*

The great breadth of the short arms is shown in Forbes' figure quoted above, but his specimen was not good enough to show the shape of the wide plates that border the narrow avenues, nor the deep punctated sculpture. The avenues are deep and narrow, the cavities for protrusion of the feet large and round. The avenues do not extend quite to the small mouth (and this is rare in starfish), towards which the adambulacral plates first become very narrow, and then appear actually to unite across the end of the ambulacrum. The upper surface is not known, but it was to all appearance not spinose.

Locality.—Caradoc or Bala ash-bed, west of Bala Lake; also Waterford, *see* Decade, I. above quoted.

The *Asterias primæva* of Sedgwick's fossil lists may be this or the next species

Palæaster asperrimus, Salter.

Pl. 23, fig. 2.

Annals and Mag. Nat. Hist., vol. xx., 2d. ser., pl. 9, fig. 1.

P. triuncialis, convexissimus: brachiis fere cylindricis, obtusis. Pagina superior tuberculis 12-*fariis plurimis exasperata, nec coronata. Ambulacra profunda, ossiculis magnis, acuticarinatis, angustis, transversis.*

A larger species than the last; and with cylindrical blunt arms, having a very convex upper surface covered with close-set tubercles. Beneath, the avenues are deeply sunk, and the bordering rows of bones (adambulacral ossicles) wide, composed of transverse narrow bones, becoming narrower towards the small mouth; but apparently not united across as in the last species.

These transverse ossicles are very convex, sharp edged, the ridge rising in some parts into tubercles. The small madreporic tubercle may be seen between the angles of the arms. The form of the species is not unlike that of *Asteriscus crassus*, Gray.

Locality.—Caradoc. A pretty species discovered in the Quakers' burying ground near Welshpool. Two specimens have been found, and more should be sought for.

Palæaster imbricatus, n. sp.

Pl. 23, fig. 8.

P. rigidus, uncialis. Radii breves conici, nec ad basin valde expansi, subcarinati, tuberculis seu jugis obliquis remotiusculis asperi.

Ray conical, its length about five lines, its breadth at base less than two lines. Only two rays are preserved; these are convex, slowly tapering, somewhat carinate above (we do not see the lower side), and ornamented by tubercles gathered into curved oblique rows, which run forward from the avenues toward the carina above, and are separated from each other by a space little more than their own breadth.

Locality.—Caradoc rocks, Llanfyllin, Montgomeryshire. The specimen is in the collection of Mr. Prosser.

Protaster? (Tæniaster) Salteri, Forbes.

Pl. 23, fig. 3.

Ophiura, Quart. Geol. Journal, vol. i., 1845, p. 20; *Protaster?* Siluria, 2nd ed., p. 208; Annals Nat. Hist., l. c.

P? disco nullo? brachiis lanceolato-acuminatis, apicibus attenuatis filiformibus, superne ossiculis latè concavis nec ornatis; ore parvo (*vix petaloideo?*).

This small species, long lost in the drawers of the late Professor Forbes, after he had given it the above name, was recovered some years since, and is now in the Woodwardian Museum, Cambridge. It was found,—a solitary specimen, in an old roadside quarry, among millions of *Orthides* and other common Lower Silurian shells.

The specimen shows nothing of the disk, and might therefore, if we could fully admit the genus *Tæniaster*, be placed in that obscure generic group described by Mr. Billings in 1858. If they are not *Protasters* that have lost their disk (*see* Siluria, p. 208) they must be admitted to form a distinct genus, and the name is a good one. The way in which the oral pentagon is formed is certainly different from that of *Protaster*. Only the large triangular terminal plates of the series which border the avenues enter into the composition of the mouth plates, while in *Protaster* proper, an elegant series of ogives is formed by the addition of the modified plates of other parts of the structure (of the ambulacral plates certainly), and most probably of the disk plates, in other words each ogive is formed certainly of four, and probably of six plates. It may well be said, therefore, that *Tæniaster* has a simple character to distinguish it. But this only appears to be the case in *T. spinosus*. The *T. cylindricus* is much more like *Protaster*; and as our species differs somewhat from both, I prefer to leave it in the genus *Protaster* for the present, as a general designation for the Ophiuroid Silurian Starfishes.*

This little species, scarcely more than three-quarters of an inch broad from tip to tip, differs in its slender whip-like arms from all the other species of *Protaster* or *Tæniaster*. The arms are broader at first, a little fusiform, and then suddenly tapering to a long slender end,—composed of numerous segments, the transverse measure of which is full twice their length. The lateral plates are oblique, short, much overlapping the succeeding distal plate, and furnished with short spines. The basal plates are triangular, not very large, in pairs, not closely placed, nor bending toward each other. The arms above (we have only the internal impression) were marked by a narrow channel, the plates deeply concave over more than half their surface;—the edge nearest the mouth being thickened and curved.

Locality.—Caradoc Slate. Pen-y-gaer, Cerrig-y-Druidion; North Wales (specimen in the Woodwardian Museum).

Agelacrinites, Vanuxem.

Edrioaster, Billings, Canadian Decades, No. 4, 1858; *Cyclaster*, Billings, 1857, not of Cotteau, 1856.

I confess I do not see the grounds on which this group has been divided, especially by Mr. Billings, whose beautiful illustrations of the genus, in the Canadian Decades, leave very little to be desired. But he has not definitely stated the grounds on which his new genus *Edrioaster* is founded.

Agelacrinites of Vanuxem † is supposed to be a decidedly sessile body, while the species described by Forbes as *A. Buchianus* is apparently not so; *Hemicystites* of Hall is also described as closely adhering to the shells of *Brachiopods*.

Still, as we do not know how far the less depressed form (*Edrioaster*) may have been attached, it is unsafe to alter names, except on better grounds than have been stated. And I therefore prefer to retain the name *Agelacrinites* for all the Silurian species.

It had no stem, at least the jointed quadripartite stem figured by Forbes in his plate, and supposed by him to be connected with it, was never found in juxta-position, and could not be a part of it. Moreover, Forbes does not make mention of the large buccal teeth, of which the marks are plainly evident, and which were first noticed in it by Prof. Wyville Thomson in a visit to our Museum.

These teeth, which must I suppose represent the "lantern" in the *Echinus*, help to show the near union of the genus with *Echinocystites* of Thomson, an Upper Silurian form, which I wish he had named *Sphæraster*.

In my view, both of these genera are sub-globular forms of *Asteriadæ*, an opinion which Prof. Thomson does not share, but which seems to be definitely supported, so far as the fossil we are describing is concerned, by Billings' authority: he would form a new group, the *Edrioasteridæ*, to include these Palæozoic forms. I think it would not be difficult to show in the group so constituted a relation to the *Echinidæ*, and I should include *Echinocystites* and *Palæodiscus* in it.

* They are true *Asteriadæ*, notwithstanding their form, so curiously illustrative of the Brittle stars. *See* Annals Nat. Hist. for 1861, vol. xx., 2d. ser., Pl. 9, f. 4, 5.

† Geol. Rep. N. York, p. 168.

A. Buchianus, Forbes.

Pl. 20., f. 13.

Mem. Geol. Survey, vol. ii., pt. 2, pl. 23, figs. 1, 2 (only).

The surface of the plates is granular, but I can see no trace of spines; nor can I see the chain-like pairs of pores on the puckered membrane, as figured by Forbes in his fig. 7. I think the artist has been deceived by the imbrication of the small calcareous plates which covered this surface.

The five indentations figured by Forbes, fig. 6, are clearly present, as stated by Wyville Thomson in his paper on *Echinocystites* (Edinb. New Phil. Jour., 1861, p. 8), and there is a great thickening of the oral ossicles, just within the mouth. All this is very confused in his figure, which, however, shows the anal pyramid of plates; and Forbes' fig. 8 shows (what he did not fully appreciate) the oval casts of the ambulacral pores, for the passage of the feet. Mr. Billings has recognized these in his transverse section of *Edrioaster*, and we have proof therefore that the so-called arms were ambulacra thickened interiorly. The ossicles had even the vaulted position common in recent starfish, and were, as in *Uraster*, thick and parallel, except where the feet passed. As in all the Silurian starfish, these suckers were in a single row.

Locality.—Caradoc rocks at Yspytty Evan, N. Wales.

Annelida.

Cruziana, D'Orbigny (Voyage dans L'Amerique Meridionale). (*Bilobites* in the plates.)

A group of large and remarkable fossils, doubtfully referred by its discoverers first to Articulata, and then (with less probability) to plants. The specimens consist of more or less elongated and convex impressions, deeply furrowed down the middle, sometimes quite bilobed, and from the median line the sides are plaited in an oblique direction, so as roughly to imitate leaf venation. They are of considerable geological interest, very similar forms occurring in the Silurian rocks of Spain,* Normandy, Britain, and North and South America. In Europe they are, as far as yet known, Lower Silurian; and are all of an elongated form, and occur in sandy strata. In the new continent they are of a shorter and rounded shape. Sir E. Logan has brought fine specimens from the calciferous sandstone of Canada, and in New York and the Western States the genus occurs under the form of *C.* (*Rysophycus* or *Fucoides*) *biloba*, Vanuxem, as high as the Clinton group or the upper part of the Middle Silurian. These broader forms have been ingeniously referred by Prof. Dawson to the burrows of crustacea (trilobites); but I think they cannot belong to them.

Cruziana semiplicata, n. sp.

Pl. 3, figs. 1–3.

Salter, in Rep. Brit. Assoc., 1852, Trans. Sect. p. 5; Siluria, 2nd ed., p. 45, Foss. 4, fig. 3, p. 45.

Description.—Linear, several inches long without diminishing in breadth (extremities unknown), often an inch and a half broad, the central furrow strong, the sides convex and bent down below the level of the furrow. Plaits numerous and close, simple or branched, oblique, and reaching from the furrow more than half way to the edge; the remainder of the sides is smooth. The plaits are generally simple, terminate abruptly at the smooth portion of the margin, and are nearly equal in length but of different thicknesses; occasionally they are branched from near their origin, and sometimes new ones are introduced as they proceed outwards. Occasionally they are fasciculated in twos and threes, and branched once or twice on their forward edge, the branches ceasing as they inosculate with the next plait. The specimen figured (fig. 6) shows pretty clearly that the frond has thickness, and was either a soft cylinder or a hollow one, the broken extremity showing the opposite face, and the cylinder having been filled with sand of a somewhat different colour to that beneath it.

The great surfaces of arenaceous flag in which I found these fossils are considerably above the lowest layers of the Lingula beds. They occur near the

* M. Prado, director of the Spanish Geological Survey, has sent us specimens from the Lower Silurian rocks of Almaden, and these are beautifully figured in his luxurious 4to. work on the Province of Madrid, 1864.

Slate Quarries, Bangor, at the head of the short glacier-marked valley Cwm Graianog,* and form the great shelving precipices of the east face of Carnedd Ffiliast. From the mode in which the matted surfaces of *Cruziana* and the cylindrical bodies called *Chondrites* occur on the rippled-marked faces of the beds, it is most probable that the latter are the tubular contents of worm tubes, or rather the rejectamenta from their bodies as they passed through the silty layers. It is by no means certain that *Cruziana* too, though at present generally arranged among fucoids or sea-weeds, may not have been a worm tube or burrow filled up also; and I shall here adopt this opinion.

I had the good fortune myself to find these specimens, and endeavoured in vain to learn whether the convex surfaces of the fossils were on the upper or lower sides of the beds: the specimens are abundant, and they in all probability occur on the upper surfaces; but only small portions of this particular bed could be observed *in situ*. Many of the precipitous faces are finely ripple-marked.

Locality.—" LOWER LINGULA FLAGS," Carnedd-y-Filiast, near the Penrhyn Slate Quarries, Bangor; Maentwrog, North Wales; also beneath the Stiper Stones, Shropshire (possibly this is only an allied species), Mus. P. Geology.

Annelide Burrows (*Chondrites, &c.*).

Pl. 3, fig. 4; pl. 4, fig. 13, &c.

Such remains as these, of an irregular cylindrical form, and from a line to an inch in diameter, are frequent enough in the sandy strata of the localities just mentioned. They often appear branched, but this appearance is almost always traceable to the crossing of the tubes over one another. They are nodose in parts, thickening and thinning again without any apparent regularity. Lastly, they are made up entirely of the sandy material of the stone itself; or, where any difference is observable, it is commonly the case that the substance of the worm-like bodies is of coarser and even purer sand than the matrix.

Chondrites acutangulus and *C. informis* (M'Coy) (Synopsis Pal. Foss. Woodw. Mus., Pl. 1 A., figs. 4, 5), are clearly of like origin.

I believe that even the branched fucoids (where such are clearly branched and not merely formed by crossing tubes) must be referred to similar agency, but these peculiar forms do not require discussion here.

Localities.— In the LINGULA FLAGS, almost everywhere; near Bangor, Maentwrog, Ffestiniog, &c., and in *all* the succeeding strata here described.

Scolites (*Annelide* Burrows).

Pl. 12, fig. 2.

These are the ordinary fillings up of worm tracks in the sandy mud, which I have ventured elsewhere to distinguish for convenience sake as *Scolites*, from the vertical double burrows, *Arenicolites*.

Locality.—Hard sandstones at the base of LOWER LLANDEILO shales above Penmorfa, near Tremadoc; (quarried) These are also common in all Lower Silurian rocks.

Arenicolites (*linearis*, Hall ?)

Pl. 12, fig. 27.

Scolithus linearis, Hall, Pal. N. York, vol. i., pl. 1, fig. 1.

I do not see how we can distinguish species among these burrows, except for some marked peculiarity in the form or arrangement of the burrow. Simply looped burrows of the same size, and in a very similar rock to that which in America is called the Potsdam Sandstone, were found plentifully by myself, and afterwards by many observers, in the Stiper Stones, Shropshire. (See Woodcut 2, p. 243, *supra*.)

Locality.—LOWER LLANDEILO or UPPER TREMADOC? Stiper Stones, Shropshire.

Scolecoderma.

I propose this term for all such membranous tubes (often much compressed) of worms, found in palæozoic rocks, as are clearly not referable to the more cal-

* Ramsay, Quart. Geol. Journ., vol. viii., p. 375.

careous, or at least semicalcareous, tube of *Serpulites*. They are very common. In a few cases it is possible we may mistake impressions of sea-weed for these; but their position in the beds, often vertical or oblique to them, will determine that they do not belong to sea-weeds; and the want of any branches or subdivision of the frond will also tend to distinguish them. Sometimes they are cylindrical, more often compressed, and we may distinguish this convenient but artificial genus, comprising probably many different genera of worms, from the common *Scolites* by its having clearly possessed a wall or tube, which renders the cast easily separable from the matrix, while *Scolites* only represents the track of the burrow. Though here instituting the genus, I am a little doubtful of the first described species.

Scolecoderma ? tuberculata, n. sp.

Pl. 5, fig. 24.

Two inches and a quarter long, and one quarter of an inch broad, when compressed, and studded all along with a double row of tubercles (in pairs opposite to the segments ?).

This is really all the description that can be given of the membranous fossil before us. It is a single cylindrical tube, not branched in any way, as a fucoid would be; and the tubercles are scarcely such as would be produced by patches of fructification. Still it has much the aspect of a sea-weed, and many would be disposed to refer it to that class. For reasons above given, I do not think it likely to be a plant.

Locality.—Lower Lingula Flags. Pentre-felen quarry, near Wern gate, on the road from Portmadoc to Criccieth, Caernarvonshire.

Crustacea Phyllopoda.

Hymenocaris.

Carapace ample, semioval, narrowed towards the front, curved downward at the sides, but not angularly bent along the dorsal line; no external eyes; antennæ ?; abdomen as long or longer than the carapace, of nine transverse segments, the last with three pairs of unequal lanceolate appendages.

H. vermicauda. Salter.

Pl. 2, figs. 1–4; pl. 5, fig. 25 (abdomen; and pl. 1, tracks of do.

Salter, Reports Brit. Assoc. Belfast 1852 (p. 63.)

H. bi-triuncialis, capite amplo, a latere viso trigono, plus quam dimidium corporis totius efficiente. Abdomen elongatum articulis 9, anticis paullulum latioribus, posticis angustioribus, ultimo (et penultimo ?) quadrato, reliquis transversis.

The characters of this crustacean, abundant in the upper portions of the true Lingula Flags, have been pretty fully given in the reports above quoted, but a few additional observations are necessary in explanation of the figures. Figs. 1, 2, 3, in pl. 2, represent the materials, such as they are, from which the restored figure 4 is made out; and in one or other of these all the parts may be detected, though a good deal altered by pressure. I have in this fig. 4 omitted the three appendages to the head, for which fig. 3 appears to afford justification, because in no specimens subsequently found (and many have been found since by the geologists of Portmadoc) has any trace of these abnormal inarticulated appendages been found. Moreover, they have so suspicious a resemblance to the tail spines, though not a trace exists of an abdomen crushed beneath the carapace in fig. 3, that it is hardly safe to trust to the mere accident of their position in a single specimen.

The carapace is convex, very thin, and shows a marginal furrow along the posterior border.

The nearly perfect abdomen (fig. 1), presented to us by Mr. J. E. Davis, shows the front segment narrower and smaller than the rest, and obliquely truncated on the sides. The abdominal joints appear to have been nine in number; they fit closely together, and their edges project very little, nor are they recurved (in this species) at the hinder and outer edges, but truncate. They must all have been convex like the carapace, from the appearances they present under pressure. They were probably, in the first five or six joints, four

times as wide as long, and gradually increase in length and diminish in breadth backwards. The surface of the carapace and body segments is covered by short wavy lines.

The last segment bears a number of appendages, formerly supposed to be four or five in number; but the new specimen figured in pl. 5 shows that there were six appendages—an outer short pair equal in length to the last segment, and then a smaller pair lying parallel and close together within these.

The tail-spines may have folded together, except when the animal required to expand them, as in many living crustacea; and when united, they might very probably form such an organ as could, when the creature swam near the bottom, have produced the indented marks on the slab figured in pl. 1. As such they have been described in detail in the Quart. Journ. Geol. Soc., vol. x, p. 210. When it was supposed there was one large spine, see fig. 4, as in *Ceratiocaris*, of course this explanation was easier still, but probably the two large spines lay close together. In all probability this is a Phyllopod crustacean allied to *Ceratiocaris*, from which it differed essentially by its entire (not bivalved) carapace, as in the recent *Nebalia*. The crust was very thin. The caudal appendages alone would separate it from any connexion with *Pterygotus* and its allies.

Localities.—Lower Lingula Flags, in fine sandstones (with *Lingulella Davisii*), Gwern-y-barcud (fig. 3); Moel-hafod-owen, and other places near Dolgelly; at Tremadoc, Ffestiniog, and at Pont Seiont, Caernarvon, fragments apparently of this species occur.

Lingulocaris.

A thin bivalve crustacean shell, with a general form like that of a *Modiola* or *Mytilus*, with scarcely prominent beaks, and *no?* hinge teeth; the surface of the carapace is covered by fine raised concentric lines.

Lingulocaris lingulæcomes, n. sp.

Pl. 10, figs. 1, 2.

Uncialis et ultra, tenuis, transversa, ovalis. Umbo vix prominens anterior, Margo anticus rotundus, posticus subtruncatus. Superficies lineis tenuissimis creberrimis perfecta.

A bivalved thin carapace, one inch and two lines wide, and only half an inch across the widest part, which is near to the posterior subtruncate end. The umbo very little elevated, but apparently convex; the anterior end rounded and short, the general surface gently and evenly raised, with, however, an indistinct obtuse siphonal ridge. The hinge margin is straight, shorter than the length of the shell, with no appearance of a hinge, but with an inflexed margin. The general shape is that of a *Modiola* or *Sanguinolites*, for which it was first taken. I owe the hint that it might be a bivalved crustacean to Professor Huxley, and I think it very likely.

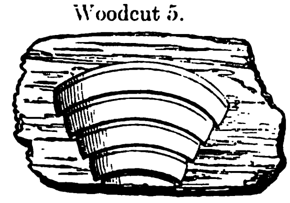
The name *Lingulæcomes* was given, as a most appropriate one, by Professor M'Coy, to what he believed to be a *Lamellibranch* shell occurring with the *Lingula*. In reality, these were no more than specimens of the *Lingula* shell pressed laterally, and so made to assume an unsymmetrical shape, see p. 334. As this, however, is truly a shell, either of some bivalve or crustacean, it is not unadvisable to use the specific name employed by M'Coy, and so recognize his diligent work among the old fossils.

Locality.—Upper Tremadoc, Garth. Mr. Ash's cabinet and Mus. P. Geology.

Ceratiocaris? latus, n. sp.

Woodcut 5.

Fig. 5.



Four body segments (only) preserved. They are many times as wide as long, arched forwards, and taper backwards very rapidly, so that the fourth is only half the width of the first; the outer ends are strongly recurved, and produced into short points.

This differs so remarkably from *Hymenocaris vermicauda* that we cannot doubt its being a different species, and very probably it belongs to the following species, provisionally referred to *Ceratiocaris*. It must have been very short and broad; and, therefore, whether it belongs to *Ceratiocaris* or not is impossible to decide without the carapace or latter body joints; the portions preserved are evidently the front rings only.

Locality.—Upper Tremadoc, Garth, east of Portmadoc.

Ceratiocaris? insperatus, n. sp.

Woodcut 6.

Fig. 6. Part of the last body-segment, *a.*; and the three tail-spines, *b. c. d.*, Cabinet of Mr. Homfray.

This fossil may well belong to the same species as the preceding.

Tail spines 3 [or 5?]; the central one lanceolate acute, at least an inch long, with a central ridge and marginal ridges; its base expanded. Side spines (*c. d.*) three-quarters of an inch long, about the same breadth, but with only marginal ridges (or it is possible there are two spines on each side, of which the outer is only half an inch long. This is hardly likely. Last body segment (*a.*) broad, with faint ridges.

It is difficult, from this single but precious fragment, to determine accurately whether the side spines *c. d.* be composed of two elements or not. Analogy leads us to expect a form in these rocks with fewer appendages than *Hymenocaris*, and more than *Ceratiocaris*, which is an Upper Silurian genus.

But on close examination of the side spines, nothing more seems necessary to explain the double markings than the impression of the marginal ridges of two side *laminæ*. There are two, more or less distinctly seen, in all species of *Ceratiocaris*, and only two.

Locality.—Dark grey shales, passage from the Lower Tremadoc to Upper Tremadoc slate (near the iron beds), Penmorfa, Portmadoc.

Beyrichia complicata, Salter.

Pl. 19, fig. 9.

Mem. Geol. Surv., vol. 2, pt. 1, pl. 8., fig. 16. Pal. foss. Woodw. Mus., Appendix, p. 136, t. 1.E., fig. 3. Jones in Ann. and Mag. Nat. Hist., 2nd Ser., vol. 16, p. 163, pl. 6, fig. 1–5.

I merely reproduce the original figure of an extremely common fossil in Lower Silurian rocks. The genus *Beyrichia* has a range from, I believe, the Tremadoc beds, certainly from the Llandeilo rocks,—to the Coal Measures. The species are usually characteristic of the several formations; *B. Klodeni*, perhaps, having the widest distribution.

Locality.—Upper Llandeilo rocks, S. Wales. Caradoc Strata all over Wales, and also in Scotland.

Trilobita.

FAM.—*Agnostidæ.* The lowest and most rudimentary form of Trilobite. A single genus includes all we know of this group; and though departing, in all technical respects, from the general character of the Trilobite, there can be no doubt *Agnostus* is a true member of the order. Without eyes, without facial suture, with only two body rings, and with scarcely a distinction between the cephalic and caudal portions, it forms as it were the root or stipes from which all other varieties of the group take their rise. *Ampyx* is blind. *Trinucleus* has no facial suture. *Illænus* has the head and tail equal and similar. But these abnormal characters are all combined in *Agnostus,* which certainly *represents* in an adult state the embryonic forms of more perfect *Trilobites*; and it is one of the oldest known fossils.

AGNOSTUS.

Though greatly resembling in some respects the young stages of higher forms, *Agnostus* shows at once its mature character by the possession of a caudal shield, as well developed, and generally quite as large as, the head. The surface too is frequently ornamented, especially the border, and the lobes are well marked out both in the cephalic and caudal portions. The leading character of the Trilobite family—the facial suture—is altogether absent, and there are no eyes.

It is instructive to find this most rudimentary form associated with other genera in which all the characters of the group are fully developed, in the same primordial zone. But it is to be noted, that either by excessive reduction, as in *Agnostus,* or excessive multiplication of segments, as in *Paradoxides,* the genera at this early period exhibit a defective organization as compared with those of later formations. There is no sort of equality in organization between an *Olenus* or *Agnostus,* and a *Phacops* or *Phillipsia.*

Agnostus princeps, n. sp.

Pl. 4, figs. 2-11; pl. 5, fig. 1.

A. pisiformis, Salter, in Siluria, pp. 53, 45, foss. 4 and 9; compare with *A. exsculptus,* Angelin, Pal. Suec, t. 6, f. 8. Decades Geol. Survey, No. 11, pl. 1, fig. 1-5.

A. latus, 7 lineas longus, scutis rotundato-quadratis, ad limbum rugoso-radiatis. Glabella subconica, tuberculo centrali antico; sulcis duobus transversis, lobis basalibus magnis instructa, sulcoque verticali ad marginem ducto. Annuli corporis bini, valde nodosi. Cauda axe magno rotundato, fere per totam caudam extenso. Margo edentulus.

More than half an inch long, with rounded-quadrate shields, the limb of which is radiated with rough branched striæ. The glabella is three-fourths the length of the anterior shield, tapering and pointed in front, with a short anterior lobe, and a dividing ridge running from it to the narrow front margin. The axis of the tail is broad, full five-sixths the length of the shield, with two transverse furrows at its origin, and with a very large rounded terminal lobe; an elongated tubercle on the middle of the tail axis; a smaller one on the glabella. No marginal spines, not even on the tail.

The largest of all known species, except the Scandinavian forms, *A. reticulatus, A. aculeatus,* Angelin; from both of which it differs by the radiate, not reticulate limb. It is much more like a smaller species, *A. exsculptus,* ib.; but, if Angelin's figure be correct, the glabella, and tail too, differ widely. The glabella is short and altogether simple, without terminal lobe or central tubercle, and the tail axis is narrow, and a good deal like the glabella of our fossil. The general aspect is much the same, but I cannot unite them without supposing much imperfection in the Swedish figures.

Locality.—UPPER LINGULA FLAGS, Penmorfa Church, and Carreg-wen farm near Portmadoc, North Wales, 1860. Also in the shales of Whiteleaved Oak, &c., Malvern; (coll. by Mr. Strickland). *Tremadoc Slate;* Portmadoc. LOWER LLANDEILO, St. David's Head, Pembrokeshire?

[I subjoin a description of the Swedish species; that it may be seen in what respects this long-known primordial species differs from others, and

especially from the *A. M'Coyii* of the Llandeilo flags, under which name I have designated the species common in the Llandeilo flags of Britain, and which was formerly published in the Silurian System as *A. pisiformis*.

Agnostus pisiformis, Linn.

Syn.—*Entomostracites paradoxus* and *pisiformis*, Linn.; Iter. Scan. [illegible]; Syst. Naturæ, ed. 12, vol. iii. 16[illegible]; *E. pisiformis*, Wahl.; *Agnostus pisiformis*, Brongn. (1822), Crust. Foss. pl. 4. fig. 4; Angelin [illegible], Pal. Suec. t. 6, fig. 7; *A. pisicauda*, ib. t. 6 fig. 8. variety.

Spec. Char.—*A. oblongus*, 2 *lineas longus, valde trilobus, capite pygidioque ovali-truncatis, lævibus. Glabella* [illegible], *in duas partes, anticam trigonam parvam, posticam oblongam*, [illegible]. *Cauda axe magno longe* [illegible], *apice obtuso; marginibus angustis* [illegible]. Lingula Flags of Sweden.]

Comparing then the Swedish figure with that given in the Silurian System of the next described species, it will be seen that the general shape of *A. pisiformis* is much longer, and the glabella narrower and more pointed; its upper lobe instead of being larger than the lower is much smaller. There are also considerable differences in the caudal shield. It has a much longer axis than in *A. M'Coyii*, crossed by a very faint transverse furrow. As to the range of the two species, *A. M'Coyii* is as yet only known in the Llandeilo flags, and the true *A. pisiformis* in the Lingula group.

A. M'Coyii, Salter.

Pl. 13, fig. 8.

Sp. Char.—*A. oblongus, depressus, capite pygidioque rotundatis, et ad thoracem contractis. Glabella oblonga, antice vix incrassata, in duas partes subæquales, posticam circularem, anticam lunatam sulco divisa. Limbus undique æqualis, lineis impressis radiatis sæpe notatus, margini angusto. Cauda capiti simillima, sed axe clavato, lobo terminali majori semielliptico, mediano transverso brevi-tuberculato, lobis anticis prominulis. Margo distinctus, brevidentatus.*

Syn.—*A. pisiformis?* Murch. Sil. Syst., pl. 25, fig. 6 (fig. 4 in text), not of Brongniart; *Diplorrhina triplicata*, M'Coy 1851, Pal. Foss. Woodw. Mus., pl. 1 E., fig. 11 [not of Corda]; *Agn. M'Coyii*, Salter (1854), in Morris' Catal. Brit. Foss., 2nd ed.; Siluria, 2nd ed. pl. 3, figs. 7, 8; Id. Decades Geol. Survey, No. 11. pl. I., figs. 6, 7.

A frequent fossil in the black Llandeilo flags of Builth in Radnorshire, and Shelve in Shropshire, but as far as I know, not found elsewhere. It accompanies the *Ogygia Buchii* and *Ampyx nudus*, and seems, like many others of its genus, to have delighted in a habitat of black carbonaceous mud, now converted into shale. It is fully described in Decade 11, and I therefore only give the diagnosis here.

Locality.—Upper Llandeilo Flags, S. Wales.

Agnostus trinodus, Salter.

Pl. 19, fig. 8.

A. brevis, semiuncialis. Caput suborbiculare, glabellâ convexâ, vix ⅔ capitis longâ, integrâ; limbo convexo. Cauda transversa, convexa; axe minuto conico, vix dimidium caudæ efficiente, utrinque bilobo, tuberculo magno. Limbus posticus convexus, à margine bispinoso et ab axe profundè sejunctus.

Syn.—*Trinodus agnostiformis*, M'Coy, Sil. Foss. Irel., pl. 4, fig. 3; in Pal. Foss. Woodw. Mus., t. 1 E., figs. 12, 13 (not fig. 11); *T. tardus*, ib., fig. 9. [*A. glabratus*, Angelin, Pal. Suec. t. 6, fig. 5]; *Agnostus trinodus*, Decades Geol. Surv., No. 11, pl. 1, f. 8. 10; *β, convexus*, Salter, in Mem. Geol. Surv., vol. ii., pt. 1, pl. 8, f. 12, 13.

The original figure in the Memoirs of the Survey was not quite satisfactory, for the tail segment (from decomposing limestone near Haverfordwest) had lost its axis-furrows and its marginal spines. It is replaced by better specimens in our Museum, from Ayrshire. The head has been found more abundantly than the pygidium, and is at once distinguished from all other British published forms (indeed from all except the kindred species *A. limbatus*) by the simplicity of its glabella, in which, and many other points, the species closely resembles *A. tardus*, Barrande.

As I have fully described this and other species for Decade 11 of the Survey Memoirs, I will content myself with pointing out the differences between our species and the Bohemian one. M. Barrande when in England saw our species, but did not identify it with his own, nor are they, I believe, to be identified.

There is no trace in Barrande's excellent figure of the slight lateral indentation in the glabella, which indicates the position of a furrow; nor of the lateral spines to the tail; they are also absent in the allied Swedish form *A. lentiformis*, Angelin. But the *A. glabratus* of Angelin, a Caradoc form from Besstorp in Vestrogothia, is far more like, and if I might suppose that the artist had made the form too elongate, and drawn the tail axis too large, I should consider it identical. The body rings in the Swedish species are very clearly shown (and ours should be sought for). The second ring differs a good deal from the anterior one.

These three species,—*A. tardus*, *A. glabratus*, and *A. trinodus*, would certainly make an excellent subgenus, distinguished by the absence of glabella furrows. But I do not, any more than M. Barrande, wish to cut up this most natural group, and therefore regard *Trinodus*, M'Coy, (*Arthrorhachis*, Corda,) as a section or subgenus only.

There was a wrong reference in my first description of this species, for I quoted Professor M'Coy's synonym for the *A. limbatus*, next described, regarding both as varieties of the *A. trinodus*, and giving the present one the varietal name *β. convexus*. M'Coy corrected this error in the Cambridge work, where he again figured two imperfect heads of the species. I hope now to have remedied all our deficiencies by the excellent specimens figured in the Decade, and chiefly obtained by Professor Wyville Thomson from Ayrshire.

Localities.—CARADOC.—Haverfordwest in two or three places; Bala and other localities in North Wales; Chair of Kildare, Ireland; Penwhapple Burn, near Girvan, Ayrshire; Shineton, near Cressage, Shropshire.

A. limbatus (not here figured).

A. trinodus, Mem. Geol. Survey, vol. ii., pt. 1, pl. 8, fig. 11 (not figs. 12, 13, which belong to the true *A. trinodus*).

SP. CHAR.—*A. oblongus, depressus.* [*Caput orbiculare, glabellâ convexâ, brevi, integrâ, limbo depresso, anticè angustato, cum margine plano fere confluenti, nec sulco distincto circumscripto.*] *Cauda semicircularis, lata, depressa, axe elevato conico, basi ad thoracem articulatâ, latâ; lobis anticis triangulatis, a tuberculo mediano oblongo sejunctis; lobo terminali fere dimidium axis efficiente, apice acuto; limbo depresso subplano, cum margine confluente.*

The tail is all I rely on for the establishment of this species; for the head, although found at the same place and very probably belonging to it, is not so different from that of the last described species as to make it certain it belongs to this. Like the tail, however, this head has the broad flattened margin, scarcely distinguished by any definite furrow from the slightly convex limb. In addition to this character, the glabella, which resembles that of *A. trinodus* in shape, reaches further forwards than in that species, so that there is not so great a width in front of it as on the sides. The posterior edge is broken, but the lobes of the neck segment seem to be smaller and narrower.

The tail is three lines wide and two lines long; truncato-orbicular, depressed except on the axis which is elevated, and distinctly circumscribed, though not by an impressed furrow. It occupies less than half the length of the tail, and is of triangular conic shape, pointed at the apex, and broad at the base next the thorax. The anterior portion has a pair of lateral lobes, triangular, transverse, and rather convex, partly separated by the oblong median tubercle, which reaches from hence to the beginning of the terminal lobe, where it ends abruptly. The intermediate or middle pair of lobes are about as broad as the basal ones. The terminal lobe is large, occupying less than half the length of the axis, and is marked off by an obscure furrow.

The limb declines gently from the axis, without any separating furrow, and is of equal width at the sides and end. The margin is flat, not so broad as the limb, from which it is only separated by a shallow depression all round. There is an obscure trace of a lateral tooth high up on each side. The anterior edge of the tail is furnished with a distinct articulating portion (as in all the species

when sufficiently perfect) and on the side-lobes the anterior edge is marked off by a deep groove.

With *A. trinodus*, the head supposed to belong to this species agrees very nearly, and only differs from it in the absence of the deep marginal groove, and in the less width of the limb in front. The tail has less resemblance, and in the great depression of all but the axis, and the conic or pointed form of that portion, differs entirely. The proportions of the axis, limb, and border also separate *A. limbatus* from either of the Swedish species *A. glabratus* and *A. lentiformis*. I do not know of any other with which it can be compared.

Professor M'Coy has united the species with the *A. tardus*, Barrande; an identification which cannot be maintained, for that species is all but identical with *A. trinodus*.

Locality.—Caradoc.—Wexford (Survey coll.).

Agnostus, sp. (allied to *A. limbatus*).
Pl. 11*a*, fig. 7, and woodcut 7.
Decades Geol. Survey, No. 11, pl. 1, fig. 12.

Fig. 7.

This is only the caudal shield of a species resembling the *A. nudus* of Beyrich (more like that species than any British one). The central portion is but faintly marked out, but is smaller in proportion to the limb than in the Bohemian species.

The length of the pygidium is less than two lines. It is long-semioval, the border concave, and is nearly as broad as the axis, which is half the length of the tail, not very strongly marked out, and has a small anterior tubercle.

The Caradoc or Llandeilo flag species *A. limbatus*, Salter, is somewhat like it in the broad and somewhat duplicated border, but differs in the much smaller axis, and more backward position of the central tubercle. Our species, imperfect as it is, is distinct from, and lies midway between, this species and the Bohemian *A. nudus*, a primordial form.

Locality. — Lower Llandeilo, Tai-hirion, west of Bala, collected by myself in 1853.

Fam. Olenidæ.

A large and ill-defined group, in some respects leaning towards the *Calymenidæ*, in others peculiar. The trilobites composing it are :—Long-bodied, with many free segments in the thorax, and very few (generally) in the post-abdomen. The *Olenidæ* are thus the very reverse of the *Agnostidæ*, which always bear them company. They range thus in geological time.—

Primordial, abundant. Lower Silurian, rare.

The family is not known to occur above the Caradoc, where the genus *Triarthrus* and *Cyphoniscus* show abnormal characters, and the group dies out.

Paradoxides Hicksii, n. s. (*Forchhammeri* on plate).
Pl. 4, fig. 12.

P. Forchhammeri? Salter, Siluria, 2nd ed., 1859, p. 45, Foss. 5, f. 2; Decades Geol. Surv., No. 11, pl. 10, f. 9 (not of Angelin).

Our specimen must, when perfect, have been more than 3 inches long; although very incomplete, enough remains to show that the species is distinct from any of the Bohemian ones, unless it may be *P. Bohemicus*, and from either of the three Swedish species described by Angelin, except *P. Forchhammeri*, to which I was therefore formerly obliged to refer it.

But there are several points in which it agrees with the latter species and differs from *P. Bohemicus*. The glabella is widely clavate, and the furrows across the base are parallel, or nearly so. The body rings, of which we have only 16 preserved, have the axis considerably narrower than the pleuræ, and the latter have only short points, and very oblique grooves. The second pleura

is not elongated, nor at all wider than the third, another point in which it differs from *P. Bohemicus*, but in which *P. Forchhammeri* does not offer means of comparison. But in the proportionate length to their width, the pleuræ agree much better with the Swedish species, the length being rather more than three times the width; while in *P. Bohemicus* it is rather less.

In both *P. spinosus* and *P. rotundatus* of Bohemia, and *P. Tessini* of Sweden, the two basal glabella furrows, besides the neck furrow, run quite strongly across. Our species therefore does not need comparison with them, as it has only one transverse groove above the neck furrow; the rest are very obscurely indicated in this specimen, which has been much compressed in an oblique direction.

Locality.—North Wales (exact locality uncertain, probably near Dolgelly).—(Certainly Lower Lingula Flags, for the same species, together with a very much larger form, the *P. Davidis*, has lately been described from the Lower Lingula beds of N. and S. Wales, and proves to be a new species.—J. W. S., 1865.)

Several species of *Olénus* are now added to the British list. The originally described one, here again figured, is the—

Olenus micrurus, Salter.

Pl. 2, figs. 5, 6.

Decade II., Geol. Survey, pl. 9 (1849); Siluria, 2nd ed., p. 45, Foss. 4, fig. 2; Lyell's Elementary Manual, 6th ed., p. 573, fig. 663.

The above references will indicate where this now well-known species has been figured. It is not, however, by any means a common fossil, and it is necessary now to distinguish it from the following species, which appears to be the ordinary form in the lower black shales of North Wales. It is easily distinguished from *O. cataractes* by the incomplete and oblique lower glabella furrows, the shape of the small smooth subtruncate tail, and by the abrupt narrowing of the hinder body rings, which also have the fulcrum placed nearer than half way out from the axis.

Localities.—Lower Lingula *Flags.*—Trawsfynydd; Dolgelly; Marchllyn-mawr; Portmadoc; all in N. Wales.

Olenus cataractes, n. sp.

Pl. 5, fig. 23.

Nearly an inch and a half long, ovate, blunt at both ends, the head wide, nearly one inch broad; the body much narrower, tapering regularly to the tail.

The head is subtruncate; the glabella moderate in size, parabolic, not so broad as the cheeks, reaching forward nearly to the narrow front margin, and about the width of that margin distant from it, furnished with two pairs of furrows, of which the lower are complete across. The eye is nearly as far forward as the front of the glabella, and somewhat remote from it. The hinder angles of the head abrupt and short, scarcely reaching the fourth segment, the spines directed backward, not outward.

Body rings 15, their axis convex, in all the segments nearly as broad as the pleuræ, which regularly decrease in length from before backwards; they are obliquely pointed, with short spines directed outwards, but very little backward. The fulcrum of the pleuræ is placed beyond the half, even in the hinder rings. Tail short, semioval, with a very wide axis, of three rings, and the sides with two furrows.

This has been for some time in the cabinet as a variety of *Olenus micrurus*. But closer examination shows many points of difference, the chief being that the axis is equally wide with the sides, and these last taper regularly, not abruptly as in *O. micrurus*. The tail is even more easily distinguishable, the width of the axis being greater than that of the sides; it has three rings, including the terminal portion; and there are two lateral furrows, not one only. *O. cataractes* has 15 body rings, *O. micrurus* 14. The head is much like that of *O. micrurus*, but the lower glabella furrows run quite across. Compared with the Swedish *O. truncatus*, the greater breadth of the cheeks, and the longer more parabolic form of the glabella, will distinguish it. I do not compare the [redacted]

Localities.—Lower Lingula Flags.—Maentwrog Waterfall, Merionethshire, in black shale strata full of *Agnostus pisiformis;* also at Treflys, east of Criccieth, Caernarvonshire, North Wales.

(*O. truncatus* is from Sweden, at Andrarum, in Scania, but I think from higher beds than ours.)

Olenus scarabæoides, Wahl.

Pl. 5, figs. 2–5.

Wahlenb. Dalman's Palæadæ. Brongniart's Crustacès. *Peltura scarabæoides,* Milne Edwards's Crustaces. *Peltura scarab.*, Angelin, Palæont. Suecica, pl. XXV., fig. 8 (mala). *O. spinulosus,* Phill. Mem. Geol. Survey, vol. ii., pt. 1, pp. 55, 239?

O. scarabæoides, Murch., Siluria, 2nd ed., Appendix, Table, p. 540.

In size, as well as form, these pressed and distorted trilobites agree well with Christiania specimens presented by Dr. Th. Kjerulf. But ours show only 12 body rings, while Angelin figures 13. Then there are two rings to the axis of the tail, besides the terminal lobe. The marginal spines are not clearly seen, except in one example, fig. 5.

I believe we may safely identify with this the small species found at Malvern, and described by Phillips under the name of *O. spinulosus?*. It is certainly not Wahlenberg's species of that name.

Localities.—Upper Lingula Flags.—Carreg-wen, near Borth, and Penmorfa Church, both near Tremadoc, North Wales; Whiteleaved Oak, Malvern.

Olenus (Parabolina) serratus, n. sp.

Pl. 5, fig. 6, 7.

Salter, Decades Geol. Surv., No. 11, pl. 8, f. 5, 1865.

(Glabella quite as wide in front as behind, with a broad neck-lobe, equal in breadth to the basal lobe. The upper lobe somewhat narrower. Fixed cheek broad, subtrigonal, equal to half the width of the glabella just below the eye.)

Tail, probably of the same species; semicircular, serrate, with short, somewhat radiating spines. Axis thick, of five prominent rings. Sides four-ribbed, the ribs duplicate and produced on the margin into short spines of less length than the limb, five on each side, the fifth pair of spines being set rather wide apart beneath the axis.

I much wish I could identify this with the common *O. spinulosus,* Wahl., for the head is very like. But the caudal shield is decidedly different, and as it in all probability belongs to the same species as the head, I feel bound to keep them distinct. The name applies to the tail only at present. The glabella moreover differs, as above described, from that of the true *O. spinulosus,* which tapers a little forward. In that species too the tail spines are greatly lengthened.

The section *Parabolina,* regarded as a genus by Angelin, was proposed by me in 1849 to distinguish the species of *Oleni* which have 12 body rings and a laciniate tail. *O. scarabæoides* might belong to this subgenus as so defined, but it clearly belongs to a different natural group, in which the cheeks are much contracted and the glabella enlarged; in the majority of *Oleni* the very reverse is the case. I believe Angelin has good reasons for supposing there are several distinct genera included under *Olenus,* but I do not quite see the way to their definition yet. The term *Peltura* may perhaps stand: but it was founded on species of *Lichas,* as may be seen by reference to Fletcher's description of the British Upper Silurian species of that genus.*

Locality.—Upper Lingula Flags.—Carreg-wen, as above.

Olenus (Sphærophthalmus) flagellifer, Angelin?

Pl. 5, figs. 8, 9.

Sphæroph. flagellifer, Ang., Pal. Suecica, pl. 26, fig. 7.

The only difference I can see between the Tremadoc specimens and the figure by Angelin, is that the glabella furrows run quite across, while Angelin gives them as only lateral. But as this character of the complete transverse furrows seems to belong to the whole of the *Sphærophthalmi,* perhaps the artist

* Quart. Geol. Journ., vol. vi., p. 235.

has not sufficiently represented it. The other characters of the sub-genus (for it can, I think, only be so regarded) are the short and wide transverse head, the cylindric glabella reaching the front margin.

Eurycaris, Angelin, again, has a broader front, and a wider and more parabolic glabella, thus leading from *Sphærophthalmus* to the true *Oleni*, of which *O. gibbosus* may be taken as the type. The characters seem to me not to be absolute in any of these sub-genera, and hence they may all, I think (and M. Barrande seems to be of the same opinion), be conveniently retained in *Olenus*.

Locality.—UPPER LINGULA FLAGS.—Carreg-wen, Borth, Portmadoc.

Olenus,—sp.

Pl. 5, figs. 10, 11.

A caudal shield only, triangular in shape, in the same slab with a head of the above or an allied species.

It has a narrower axis, with less distinct ribs than the tail of *O. gibbosus*, Wahl., and the limb is wider, and with only two duplicate ribs visible on its forward edge. *O. gibbosus* has several, and according to Angelin's figure the upper one runs out into a spine; but specimens in the Geol. Soc. collection do not show this spine, nor does Dalman's figure. Yet it is particularly noted by Angelin (whose descriptions are always clear, though far too short for easy recognition of a species) and is moreover in agreement with the general character of the genus. Possibly the two sexes differed in this particular.

Locality.—UPPER LINGULA Flags.—Carreg-wen, Borth, Portmadoc. Presented to the Mus. P. Geology by F. Ash, Esq., of Portmadoc.

Olenus (*Sphærophth.*) *alatus*, Bœck.

Pl. 4, fig. 3.

Olenus alatus, Bœck., Gœa. Norwegica, p. 143; *Sphærophthalmus alatus*, Angelin, Pal. Succ., pl. 26, fig. 9; [*Olenus bisulcatus*, Phill., Mem. Geol. Survey, vol. ii., pt. 1, p. 55, fig. 1, 2?]; Salter in Murchison's Siluria, 2nd ed., pp. 47, 538; in Decades Geol. Surv., No. 11, pl. 8, f. 6, 1865.

Our specimens are not very perfect, but there is no difference of importance between these and the figures by Angelin; and there are specimens in our museum of the Norwegian species, with the same characters. The great width of the cheeks in proportion to the glabella, and the strongly arched spines, are easily recognizable characters. The upper furrows are very obscure in our specimens.

I fear *Olenus bisulcatus*, Ph., from the Malvern black shales, cannot be separated from this species.

Localities.—UPPER LINGULA Flags.—Carreg-wen, Borth, Portmadoc; Penmorfa Church, west of Tremadoc; White-leaved Oak, Malvern.

Olenus (*Sphærophth.*) *humilis*, Phill.

Pl. 5, fig. 12.

Memoirs Geological Survey, vol. 2, pt. 1, p. 55, figs. 4, 5, 6, 1848, Salter; Decades Geol.Surv. No. 11, pl. 8, f. 9, 11, 1865.

This is only here noticed to remark that this minute species is well characterized by the very *narrow* instead of *wide* cheeks. Yet, in other respects, it is a perfect *Sphærophthalmus*; and such a blending of characters indicates that we are dealing with sub-genera rather than distinct and well-marked generic types. It is more fully described in our Decade 11.

Locality.—UPPER LINGULA Flags.—Black shales, Malvern, common.

Olenus impar, n. sp.

Pl. 8, fig. 4.

O. uncialis, capite transverso semilunari, lato; corpore angustissimo. Axis thoracis latus convexus. Pleuræ breves falcatæ. Fulcrum ad axin appressum. Glabella marginem latum attingens, lobis duobus obscuris. Genæ quam glabella latæ, oculis parvis medianis, spinis prælongis, subparallelis.

A species with broader axis to the body, and smaller pleuræ than most others, except the *O. scarabæoides*. From this it differs materially in the great breadth

of the head, and the long parallel head-spines, giving it the aspect of a small *Paradoxides*, under which name Mr. Ash sent it me to figure.

The whole length is less than one inch, the head broad and rounded, transverse, about twice as wide as long, with a moderately long parabolic glabella, reaching the rather broad front margin; the cheeks in width about equal to the glabella, and having the eye midway and about half-way up the cheek, small, prominent; the head spines very long, nearly straight, parallel, and reaching as far as the extremity of the whole body. Glabella furrows oblique, not crossing the glabella, two on each side besides the strong neck furrow.

I can only count eight body rings, but there may be five or six more, for we have not the entire body. The axis is convex, much broader than the pleuræ in front, at about the seventh or eighth ring equal to them, and thence the pleuræ increase in proportional length. These are falcate, the tip considerably curved, the fulcrum very close to the axis in all the rings, just as in *Remopleurides*, to which genus our fossil bears a close resemblance.

It may be compared with *Olenus scarabæoides*, as to its body rings, but even that species has them not nearly so short proportionally; the head is however quite unlike.

Locality.—Upper Tremadoc Slate. Penclogwyn, near Portmadoc, Mr. Ash's cabinet.

Dikelocephalus. D. Owen.

This genus, as defined by Dale Owen's figures, approaches very closely to *Olenus*, having the complete transverse furrows to the glabella; and, in some of them at least, the eyes, though not remote from the glabella, are connected with it by means of an ocular ridge. The pygidium, judging by his figures, is truncate behind, but not always produced into spinous angles. And it has a shortened many-ringed axis with numerous radiating furrows on the tail. I take *D. minnesotensis*, *D. meniscaensis*, and *D. Pepinensis* as types.*

With these external characters, it is hardly right even to join our species *D. celticus* to the genus, as Mr. Billings in his excellent paper on the Quebec trilobites† has done with the *D. magnificus*. The glabella is quite different. But I only follow him with this and the other species, because I am unwilling to add to generic names, where the materials are insufficient. Such species as his *D. planifrons* (l. c., p. 309, fig. 6) and our *D. discoidalis*, pl. 5, fig. 19, are clearly more related to *Ogygia*, an affinity which was perceived by Mr. Billings. As I have not the means of judging of the limits of this genus, I must hope that my friend will re-examine his rich materials, and institute a genus at least for the forms resembling *Ogygia*. In the meantime we will give all of them the provisional generic name. Is not *Centropleura* of Angelin a good generic group, though incompletely defined?

Dikelocephalus (*Centropleura ?*) *furca*, n. sp.

Pl. 6, fig. 4; and pl. 8, fig. 10. (fig. 9?)

D. [*capite transverso, margine frontali lato, glabellâ longâ, obscure sulcatâ.*] *Cauda subpentagona* (*sesquiuncialis*) *semiradiata, margine lævi quam axe latiori, margine antico obliquo, postico truncato, spinisque duobus latis brevibus approximatis.*

A pygidium an inch and a half wide, and, including the spines, one inch long, of a rough rhomboidal shape, rounded on the anterior edges, which retreat rapidly from the axis towards the widest part, and thence the tail contracts towards the hinder angles. These are produced into short blunt spines, and between them the hinder edge is straight and truncate.

The axis is long, conical, more than one-fourth the entire width (in *D. celticus* it is less than one-fifth), reaches nearly three-fourths down the tail, and is marked by six rings besides the rather blunt terminal piece (there is no appendix as in *D. celticus*). The sides are grooved by at least five principal furrows, faint where they join the axis, then stronger just before they bend down obliquely backwards, to follow the outline of the front edge. They do not nearly reach the margin, but leave a broad plain band, a quarter of an inch broad. The

* *D. granulosus* is a true *Olenus*.
† Canadian Nat. and Geologist, vol. v., p. 307.

incurved under portion (*caudal fascia*) is broader than this band, extending more than half way up the ribs; it is rather finely striate.

Compared with *D. celticus* (pl. 5, figs. 21, 22) our Upper Tremadoc species has the tail more pentagonal, the axis much broader and without an appendix, and moreover it has fewer axal and lateral ribs, the latter reaching not nearly so far toward the edge. The posterior margin is abruptly truncate (not rounded and emarginate), and the two blunt spines effectually distinguish the species.

The approximate tail-spines, and the faint half-developed lateral furrows, will distinguish it from *D. Minnesotensis*, Dale Owen. The *Centropleura dicræura* of Angelin, from the beds of his region B. C. (which answers well to the Tremadoc Slate), is by far the nearest species to ours. But it differs in the much closer tail-spines, and the elongated continuous lateral furrows.

Locality.—UPPER TREMADOC. Moel-y-gest; and a variety? with stronger lateral furrows occurs at Penmorfa. Both are in Mr. Ash's cabinet.

Pl. 8, fig. 9.

The head, which we figure from Mr. Ash's specimen, most probably belongs to the same species as the tail described above. It differs from *D. celticus* in the longer glabella, which all but reaches the marginal furrow in front, and in the greater breadth of the margin itself. The eyes are placed further back. The glabella lobes are not distinct.

Locality.—Same as above.

Dikelocephalus? (*Centropleura?*) *celticus*, n. sp.

Pl. 5, figs. 21, 22.

Caudal shield entire, ¾ inch long, 1⅛ inch broad; rotundato-quadrate, the posterior and anterior angles being rounded off, abruptly truncate and emarginate behind, and with no serrations whatever. The axis is narrow, prominent, gently tapering for nearly two-thirds the length of the shield, then abruptly attenuated into a narrow appendix as far as the margin. It is seven-ringed before its abrupt contraction, thence smooth. The sides have seven curved ribs, including the conspicuous front (marginal) one. These ribs are directed first outwards, then bent abruptly backward at the first fourth of their length, and so running obliquely to the margin; the second and third are duplicated. The posterior notch to which the appendix of the axis runs, is but shallow, but quite distinct.

There is a great general resemblance to the species so well figured by Billings in the Canadian Naturalist and Geologist, vol. v., p. 307. The axis of ours is however longer, almost double the proportionate length, the ribs more numerous, and the margin entire. It is still more like Angelin's *Centropleura? dicræura*, pl. 41, fig. 9.

I think, as above said, that a new genus should be constituted for these species. Meantime, they are primordial fossils in this country, Upper Lingula flag and Tremadoc slate; while in America they probably help to fix the horizon of the celebrated calcareous beds of Quebec.* As these breccias and the intercalated shales must, from the *Graptolites* they contain, be older than the Llandeilo Flags and the equivalents of our Lower Llandeilo series, so it is probable that their lower beds should contain fossil genera of primordial date, mixed with others of later age.

Locality.—UPPER LINGULA Flag, Ogof-ddu, east of Criccieth, in black slate.

Dikelocephalus? (*Centropleura*)? *discoidalis*, n. sp.

Pl. 5, figs. 18, 19.

The glabella is a little narrowed in front, but then clavate, so as to give a somewhat urceolate shape. It is marked clearly by four short furrows, of which the second from the base is oblique from above inwards, and longest; the third is direct and short; the uppermost (fourth) very short and oblique from above outwards, towards the eye.

We have not the free cheek in its place; it is however greatly expanded and flattened, the eye is strongly lunate, smooth.

* There has been much discussion as to the true position of the Quebec beds. Sir W. Logan and Mr. Billings have now fully (Canad. Reports, and Geology of Canada, 1863) cleared up the [redacted]

Of this, fragments only were obtained, but in considerable quantity, and I doubt not perfect specimens might be found. The front of the head is greatly expanded and flattened (without any marginal furrow) like the free cheeks. Our fossil agrees in all respects with the figure of *Dikelocephalus? planifrons*, Billings, except that the glabella is shorter. It is sufficient for our purpose that the type is exactly the same. It is very like *Ogygia* in the number and arrangement of the glabella furrows, and, according to Mr. Billings, in the labrum also it is like that genus.

Locality.—Ogof-ddu, Criccieth. UPPER LINGULA FLAGS.

Dikelocephalus? (*Centropleura?*) sp.

Pl. 5, fig. 20.

Caudal shield semicircular, the forward edge much curved, the axis narrow, tapering, convex, four-fifths the whole length of the tail, with eight distinct narrow rings, abruptly conical at the apex, then lost in the broad margin; sides with six curved ribs, the principal ones duplicate. Not at all likely to be a *Dikellocephalus*, but quite similar to the caudal shields figured as of that genus in p. 311 of Mr. Billings' memoir, but not named.

Locality.—Ogof-ddu, as above.

Conocephalidæ.

If the *Olenidæ* are an ill-defined group, it is only because it is difficult to see the exact point at which they become distinct from this, which often accompanies them and ranges with them in time.

The *Conocephalidæ* may be assumed at present to embrace such genera as *Conocephalus*, *Solenopleura*, *Elyx*, (and doubtfully *Ellipsocephalus* and *Arionellus*,) together with *Sao*, which is a typical member of the group, and shows its close affinity with the *Calymenidæ*, and also *Angelina*, which has the facetted pleuræ and general character of this group, but might be equally well referred to the *Olenidæ* by its habit.

Conocoryphe. Corda.*

(*Conocephalus*. Barr.)

If this genus is to include such extreme forms as the (*Harpides?*) *rugosus* of Angelin, or the *Conocephalus Emmerichi*, Barr., as a middle term, and *C.* (*Ctenocephalus*) *coronatus*, Barr., at the other side, it is evident that we are allowing a wider range of variation than is usual in trilobite genera. It is more probably a small family group, and will hereafter be broken up, but I entirely agree with M. Barrande that we are not in a position to do this successfully as yet. It is safer to regard the principal variations as subgenera, and in this view, the two species here described will fall under quite distinct groups. For the characters of the genus see Barrande's Monograph.

His *C. Emmerichii* and *C. invita* will form one group or section, distinguished by the great size of the approximate eyes, comparatively large and well distinctly lobed glabella, 14 body rings, and small caudal shield, and might be called *Conocoryphe* proper.

Solenopleura, Angelin, is another quite distinct subgenus, with short glabella, scarcely lobed, small, remote eyes, few (11 or 12) body rings, and a moderately-sized caudal shield.

Conocoryphe invita, Salter.

Pl. 4, figs. 5, 6, 7; pl. 7, fig. 7.

Decades Geol. Surv., No. 11, Pl. 7, fig. 6.

C. capite (solùm adhuc cognoto) latimarginato, angulis brevispinosis, glabellâ urceolatâ, utrinque bisulcatâ; oculis longis, ad glabellam appressis; caudâ angustâ, axe conico 4-annulato.

We have portions of the head, and the tail. The facial sutures converge greatly from the margin to reach the eye, which is very long, reaching two-

* I am compelled to use M. Corda's name (Prodr. Monog. Bohm. Tril., 1847) on account of the previous employ of Zenker's name *Conocephalus* as a genus of insects. But I adopt M. Barrande's view of the generic characters.

thirds the whole length of the glabella. The glabella furrows nearly meet in its middle region, and both pairs are very oblique, the basal pair almost meeting the neck furrow.

This species so nearly resembles *C. Emmerichii*, Barrande, that, were it not for the glabella having only two pairs of furrows, it might readily be mistaken for that species. The glabella is longer, of an urceolate shape, and with the furrows reaching much further into it. The eyes are not quite so long, and are set close to the glabella, which is not the case in the Bohemian species. The tail is longer and narrower.

C. invita, with these points of difference from the Bohemian species, is nevertheless an excellent British representative of it. The next described species belongs to the same section of the genus.

Locality.—UPPER LINGULA FLAGS. Penmorfa Church, Tremadoc, North Wales.

Conocoryphe abdita, n. sp.

Pl. 5, fig. 13.

Head three-fourths of an inch long, very broadly margined in front, with a crenulate marginal furrow. Glabella more than half the length of the head, with three lateral furrows, the lowest very oblique, separating a narrow triangular lobe, the upper furrows short.

This is figured, as being clearly a distinct species from the *C. invita*, though closely allied. It has a very broad front beyond the glabella, the marginal furrow of which is crenulated as in *C. invita*, but the space in front of the glabella is twice the size. It has long eyes, as in that species, reaching from the upper furrow to the base, but remote from the glabella, not close to it. The facial suture takes a wide curve outwards beneath the eye.

I find no species like it in Angelin's figures, unless some of his supposed species of *Proetus*, Plate XVIII., may possibly be allies, but to Barrande's *C. Emmerichii* both this and the preceding species have the closest affinity.

Locality.—UPPER LINGULA Flags. Ogof-ddu, near Criccieth, in black pyritous slate.

Conocoryphe, sp.

Pl. 5, fig. 14, (fig. 15, tail?).

A very imperfect fossil, only the central part of the head being preserved. The forward position of the eyes, which are about one-fourth down the glabella, and very near it, makes the species more like *C. Sulzeri* than any of Angelin's figured species. But the glabella is as wide in front as behind, the lobes well marked, the margin defined by a shallow punctate furrow. A short ridge connects the eyes with the glabella, and the facial suture takes a bold curve outwards beneath them; the neck furrow is near the posterior margin. There is no saying if the segments and tail, fig. 15, belong to this or the previous species; they belong to a *Conocoryphe* of large size.

Locality.—With the above, at Ogof-ddu.

Conocoryphe, sp.

Pl. 5, fig. 16.

This caudal shield, which has a broad four-ringed axis, rapidly tapering, and three curved duplicate ribs on the sides, is most probably a species of *Conocoryphe*, and may belong to one or other of the foregoing species.

Locality.—Same as above, Ogof-ddu.

Conocoryphe? simplex, n. sp.

Pl. 5, fig. 17.

E. capite latissimo transverso, $\frac{4}{5}$ unciæ longo. Glabella quadrata, obtusa, truncata, lobis nullis. Oculi remoti, cum glabellâ jugo obscuro connexi. Margo anticus angustus, bene scriptus.

Distinct from any of the other Trilobites in the Upper Lingula flags, this portion of a head may receive a name. It appears to be allied to the so-called *Calymene leiostraca*, and *C. holometopa* of Angelin. But it differs from both by the less size of the glabella, which is about two-thirds only the length of the

head, and must have been very wide. The reference to *Conocoryphe* is only provisional at the best. The glabella is too convex, too short and truncate in front, the eye too forward, the facial suture not direct enough beneath the eyes. And yet this genus is the nearest to which I am able to refer it.

Locality.—Upper Lingula Flags. Penmorfa Church.

Conocoryphe vexata, n. sp.

Pl. 8, fig. 7.

C. capite ¾ unciæ lato, semicirculari; glabellâ brevi, longâ quam latâ, depressa, oblongâ rotundatâ; genis regulariter convexis; spinis brevibus; oculis medianis, ad glabellam approximatis.

An obscure species, of which we have only the head, and that is ¾ of an inch broad, and not above four lines long. The glabella as long as broad, four-fifths the length of the head and less than one-third its breadth, oblong, with rounded upper angles, not parabolic, and quite as broad forwards as behind. It is very gently convex, and shows but obscure traces of furrows. The neck segment is but slightly marked off, and the marginal furrow which runs round the flattened cheeks rather faintly marked. The space in front of the glabella is broader than the narrow front margin, and is regularly and gently convex, as are the cheeks with which it is continuous.

The eye is small, placed near the glabella and half way up the head. The facial suture curves largely out both above and below the eye, cutting the posterior margin at about two-thirds out. The angle is shortly spinous. It differs from the other and allied species as much as these forms usually differ from each other. It has a much shorter head and glabella than *C. verisimilis* figured in plate 6, or *C. olenoides*, plate 8; and the absence of glabella furrows and more approximate eyes easily separates it from *C. depressa* next described.

Locality.—Railway behind Penmorfa village. Beds of passage between Lower and Upper Tremadoc. These beds naturally combine the fossils of the upper and lower series, and, till the order of succession was fully established, gave us a great deal of trouble.

Conocoryphe (*Solenopleura*) *depressa*, Salter.

Pl. 6, figs. 1, 2, 3.

Ellipsocephalus depressus. Siluria, 2nd ed. p. 47, Foss. 7, f. 2.

C. ovata, tripollicaris, depressa, capite subtruncato brevi. Thorax segmentis 12. Cauda 3-annulata. Glabella brevis, subovata, truncata, sulcis basalibus obliquis longis, reliquis obsoletis. Oculi parvi, submediani, a glabellâ dimidium diametri ejus remoti. Thorax pleuris latisulcatis, rectis, truncatis. Cauda axe lato 4-annulato, lateribus bisulcosis.

Our specimens are all much flattened, and the species therefore must have been a depressed one. The head is very transverse, more than twice as broad as it is long, and truncate along the front. Of this the glabella occupies rather more than one-third in width, and is of a parabolic shape, or rather suboval; the lower pair of glabella furrows are distinct, oblique, and rather long. The eye is small, set rather far forward, and placed away from it for a space equal to half the diameter of the glabella. The ocular ridge is distinct. The front body rings are not quite so wide as the axis, and have the pleuræ reflexed from the fulcral point; the middle pleuræ are rather wider than their axis, and are direct to their truncated tips; only the front ones bend backward. The body becomes much narrower behind.

A fine lineation parallel to the margin occupies a broad band round the thoracic segments, but is more conspicuous in the tail. The axis of the latter is broad and parabolic rather than conical, and reaches nearly to the margin; the side lobes have two distinct furrows.

Locality.—Lower Tremadoc, Wern, Penmorfa; and above Penmorfa Church.

The specimen figured under the above name in Siluria was stated to have come from the upper part of the Lingula Flags, and this is so far true that the dark slaty beds, in which it is found, were not then separated from the Lingula Flag proper. It however occurs in plenty with *Ogygia* and *Niobe*, and lies somewhat above the *Dictyonema* beds; so that it is to be reckoned among the lower Tremadoc fossils.

The head was not known at first,—but only the 12 body rings (the whole number) and the caudal shield; and on sending it to M. Barrande, he kindly compared it with a large unpublished species of *Ellipsocephalus*. The number of body rings is too few for the usual forms of *Conocoryphe*, but the section *Solenopleura* has exactly the appearance of our fossil. In this subgenus the glabella furrows are but slight, sometimes absent; the eyes remote, with but a faint ocular ridge, and the body segments fewer. Angelin does not figure more than 11, our species has 12, and their ends are truncated, not pointed or recurved as in *Conocoryphe* proper.

Conocoryphe ? verisimilis, n. sp.

Pl. 6, fig. 13.

C. praecedenti simillima, nisi glabellâ longiore illobatâ, genisque latioribus, oculis propioribus. Pleuræ sulco angustissimo exaratæ, apicibus obtusis haud truncatis.

At first sight extremely like *C. depressa*, but on close examination the glabella appears to be longer, of a parabolic form, and quite destitute of lobes. The head is truncate as in *C. depressa*, but the eyes are nearer to the glabella, the cheeks consequently broader, the neck furrows almost obsolete.

The thorax rings are about similar in proportion to those of the species above quoted, but are abruptly narrowed in the hinder part. Their fulcrum is nearer to the axis, placed at about half way out, their groove shallower, extremely narrow and sharp, instead of broad and deep, and the tips, though blunt, are oblique, not truncate. We have, as yet, found no tail.

Locality.—Above Penmorfa village. LOWER ? TREMADOC.

Conocoryphe ? olenoides, n. sp.

Pl. 8, fig. 6.

A small species, which has so well-marked a head that it may be named *C. olenoides*. I wish we had more perfect materials.

The glabella is even longer than in the last species, all but reaching the front margin. The cheek is narrow, the facial suture in front is near the glabella, as is the very small eye, thence the facial suture takes a wide curve out, and cuts (not the posterior margin) but the outer margin, just in advance of the rounded angle. Taking this and some appearance of a projection on the front margin into account, the genus is not quite certain.

Locality.—Garth, Portmadoc, in UPPER TREMADOC.

Angelina Sedgwickii, Salter.

Pl. 7, figs. 1–5.

Decades Geol. Surv., No. 11, Pl. 7, f. 1–5.

A. Sedgwicki, Salter, Siluria, 2nd ed., 1859, p. 53, fig. 2., Foss. 9. *A. subarmata*, ib., fig. 3 (specimens pressed laterally and lengthened).

GENUS.—*Angelina*, Salter (Class *Crustacea*; order, *Trilobita*; family, *Conocephalidæ*). Depressed, head smooth and with long posterior spines, eyes small, sub-median, without ocular ridge; glabella lobeless. Body segments 14-15 with an angular fulcrum, facetted for rolling up. Tail of few (4-5) segments. Labrum emarginate.

A. ovata, segmentis trunci 15, *axe quam pleuris paullô angustiori, caudâ 2-3-annulatâ, utrinque bispinosâ.*

The new forms illustrated on our plate were part of the results of a survey by myself in 1853 of the "Lingula flags" and overlying beds, in the mountain region extending from Tremadoc to Ffestiniog, and thence to Arenig-fawr, west of Bala.

The *Angelina Sedgwickii* was supposed, when the second edition of Siluria was printed, to belong to beds a little below the Lower Llandeilo zone, and these were regarded as passing down into the top of the Lingula flags themselves. A large species of *Ogygia* being associated with them rendered this somewhat doubtful, and the geological position is now better ascertained. This new genus is characteristic of the *uppermost* portion of the Tremadoc slates.

The affinities of the new genus are equally balanced between *Olenus* and *Conocoryphe*. *Angelina* differs from *Olenus* by having the pleuræ grooved

and facetted for rolling up, instead of flat and produced into points, nor do we know of any *Olenus* that is totally without glabella furrows. It is this latter character, with the occasionally spinose tail, which distinguishes it from *Conocoryphe*; but this is combined with some characters of *Olenus*, such as the long head spines, less marked segmental furrows both axis and margins, indicating probably a thicker crust; and the much less inflected suture with the eye placed nearer to the axis. It wants too the ocular ridges of *Conocoryphe*.

From *Arionellus* the less number of body rings separates it, and that genus has so broad and expanded a margin, which is without a furrow, and the facial suture so far outwards, that there evidently is but little affinity with *Angelina*. The genus is named in honour of M. Angelin, who is carefully illustrating the old rocks of Christiania. Two fasciculi of his quarto work are already published, and we wait impatiently for the remainder. *Calymene? sclerops*, t. xx. f. 3, of Angelin's work, may very possibly belong to this genus.

Description.—Fully three inches long (one fine specimen is nearly four inches), of a broad oval outline, the head blunt, and the tail only moderately pointed. The head occupies less than one-third of the length, and is semicircular, but rather truncated in front; a narrow equal margin, not raised or thicker in front, runs all round, scarcely broader than the occipital border of the cheek, and continuous with it; an equal space separates this margin in front from the glabella, which is parabolic, much longer than broad, and quite destitute of any lobes. It is about equal in width to the cheeks (exclusive of their margin). The cheeks are gently convex, smooth, and bear the small curved eye midway, but nearer the glabella than the marginal furrow. The facial suture is nearly vertical to them above, and then turns sharply outwards to cut the posterior margin at its outer third.

The labrum is seen on one or two specimens (fig. 5). It has a central raised portion, separated by rather a deep groove from a flat margin, which is broadly and abruptly truncate at the apex. It is a little like that of *Lichas*, but is without the terminal notch, and differs from that of *Olenus* by its broad margin. *Conocoryphe* has a labrum without so broad a margin, and not nearly so truncate.

Thorax of 15 segments; the axis narrower than the sides, gently convex, and tapering quite regularly backwards. The pleuræ are nearly direct, slightly produced and bent back at their ends, and grooved throughout. They are bent down a little from the angular fulcrum, which is placed at rather more than one-third in front, (our figure shows it too far out at this point,) and much less than one half in the middle segments. The hindermost segments are scarcely at all produced or curved backwards; all the segments are facetted for rolling up. The pleural groove is deepest beneath the fulcral point, and, as beyond this the facet bounds it in front, and the posterior edge of the segment is convex beyond the fulcrum, the groove becomes an elongated rhomboidal depression; a feature never seen in those genera in which the faculty of rolling up is lost, or even very limited.

The tail is more pointed than a semicircle, the axis not as broad as the sides, with two distinct rings, and a bluntish terminal portion not reaching the margin. The sides are marked by two lateral furrows which just reach the margin, opposite to the two short lateral spines. These furrows are duplicated. The incurved under margin (caudal fascia) is very narrow, but convex.

The compressed and elongated specimens, figs. 3 and 4, were formerly considered to be of a distinct species, not however on account of the form, which I was aware might be due to pressure in great part, but on account of the spinose border to the tail, a character not at the time seen in figs. 1 and 2. A noble series of specimens, distorted in every possible way, have been transmitted by Mr. D. Homfray of Port Madoc, who collected them at my request, and by Mr. F. Ash of the same place.

These specimens show 15 segments; our figured specimens only showed 14, and they prove clearly that the spinose border to the tail occurs in all well-preserved specimens, yet in some more distinctly than others. And the great difference in appearance between figs. 2 and 3 is entirely due to the different direction in which they have been pressed in the stone. The pleural grooves in the one case are all but obliterated, in the other they are deepened (fig. 2), and the spinose border to the tail appears to be increased in length; in fig. 2 it is reduced. The somewhat greater space in front of the glabella, and the long

head-spines in fig. 3, are differences which may possibly (if they be found constant) be referable to sex.

Locality.—UPPER beds of the TREMADOC slates, Garth hill, east side of the Traeth Bach, Tremadoc, North Wales, also Portmadoc quarries, and at the Ynys Tywyn, in similar beds. (Mus. Pract. Geol.)

Fam. Asaphidæ.

A large unwieldy group of great trilobites, which are characteristic strictly of Lower Silurian rocks;—the exceptions to this geological position are very rare. The eyes are smooth, the facial suture ends on the posterior margin. The body rings 8, rarely less or more. The tail always of large size, and usually of many segments. The labrum various in shape. While on the one hand there is some analogy with the *Calymenidæ* through the genus *Homalonotus*, the group also approaches the *Olenidæ* by such forms as *Dikelocephalus*, and ranges up to *Proetidæ* with a real affinity by means of *Stygina*, while it has abnormal and rudimentary members in *Illænus* and *Æglina*. See Monograph of Brit. Trilobites, Paleont. Soc. 1866.

Its geological range commences with the earliest known strata above the true primordial zone, into which if it enters at all, it can only be by such doubtful genera as *Bathyurus*, Bill.

Except in *Illænus*, it does not rise out of the Lower Silurian, and it is very rare even in Llandovery or Middle Silurian rocks. *Niobe*, *Psilocephalus*, *Asaphus*, *Ogygia*, and their subgenera, one or the other of these genera, are characteristic of every locality where Tremadoc, Llandeilo, or Caradoc strata are found. *Asaphus*, or *Isotelus*, is the largest of *Trilobites*, excepting, of course, *Paradoxides* among the *Olenidæ*.

Asaphus (*Isotelus*) *affinis*, McCoy.

Pl. 8, fig. 15,* pl. 12, fig. 4?

REF.—*Isotelus affinis*, M'Coy, in Synopsis Foss. Woodw. Mus., pl. 1, F., fig. 3?

It is not certain that this is identical with Professor M'Coy's very imperfect specimen, but I wish to keep that species in mind, as it may eventually be included with *A. Homfrayi*.

Oblong-oval, 2½ inches long, of which the head measures more than a third, and is rounded in front; the glabella is very obscurely marked, and has no furrows. The facial suture curves boldly out above the eye, and cuts the margin considerably outside of it. Below the eye, which is more than halfway up the cheek and close to the glabella, the suture again curves largely out.

Body shorter than the head, but as long as the caudal shield. Axis broader than the sides, and not strongly separated from them. Pleuræ flat as far as the fulcrum (which is at one half in the middle rings), then curved rather than bent down. Facets broad and very well marked. Pleural groove obscure, except just beneath the fulcrum.

Caudal shield larger than a semicircle, but proportionably rather short, without segmental furrows, except the uppermost on the sides. Axis narrow, tapering, well defined, and reaching three-fourths the length of the shield; its end not prominent. Caudal fascia broad, striate.

The under side of the head has the broad epistoma well divided by a strong vertical furrow, as usual in *Asaphus*. The labrum is subquadrate, broader above and narrower towards the truncate tip. It appears not to be at all bilobed, and therefore scarcely agrees with the character of the genus. A concentric furrow and two shorter ones above it are plainly to be seen.

A. affinis resembles some Swedish species of the section *Cryptonymus*, but the course of the facial suture distinguishes it from *A. raniceps*, though the caudal shield is like; the eyes too are smaller. And the course of the facial suture is all we have to separate it from the associated species *A. Homfrayi*; while from *A. gigas* the distinct marking out of the axis will be sufficient.

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* Mr. F. Ash, of Portmadoc, believes that this specimen is only an imperfect one (with the front bent) of *A. Homfrayi*. It is quite possible. And in that case the two species, *A. affinis* and *A. Homfrayi*, would merge into *A. affinis*: at present I keep them separate. These both differ [redacted]

Locality.—UPPER TREMADOC. Pen-y-clogwyn, S. of Portmadoc, in flinty slate, much compressed by cleavage; Garth, Penrhyn; and near Llanerch, by the road side, on the way to Treflys. Pl. 12, f. 4, was found at Tyddyn Dicwm, above Penmorfa.

Asaphus Homfrayi, n. sp.

Pl. 8, figs. 11—14.

Section *Isotelus?* Facial suture ending in an ogive on the upper surface. Glabella not distinct, and axis of the tail very obscurely marked out. Labrum deeply bilobed.

A. (Isot.) longiovatus, lentè convexus, capite ad frontem subangulato, angulis brevispinosis. Oculi submediani, parvi. Axis caudæ longus, ad apicem prominulus.

The perfect figured specimen, lent by Mr. Homfray, is much elongated on the plane of cleavage; and its true length is probably not 3 inches,—the breadth 1½: compressed as it is the measures are 3½ by ¾ inch.

We have many specimens, in a more or less perfect state, presented by Mr. Homfray; and his cabinet and that of Mr. Ash contain very perfect examples. The head is more than a third of the whole length, and longer than the thorax, which in its turn is longer than the caudal shield. Head semioval, rather pointed in front, and with very short posterior angles, depressed broadly round the margin; the glabellar portion scarcely marked out. The eyes are placed nearly half way up the head, are small (two lines long) and with the facial suture curving out boldly beneath them, and cutting the posterior margin more than half way out from the axis. Above the eye they form a narrow ogive, and nearly follow the front margin. On the underside of the head the vertical furrow on the epistoma shows distinctly through the cast.

The labrum is imperfect, but shows a strong marginal furrow, and two small lateral ones.

The body rings have the axis as broad as the sides, and moderately convex. The pleuræ are flat as far as the fulcrum, truncate at their ends, and have but a slight groove, which reaches only two-thirds their length. The fulcrum is at one-third in front, and at less than half in the middle rings. The caudal axis extends three-fourths down the smooth tail, very indistinctly marked above, but in some states crossed by several rings, and prominent at the tip. This is not quite a true *Isotelus*, but shows some tendency to unite the characters of two subgenera, *Isotelus* and *Basilicus*; the course of the facial suture is characteristic in both. It differs from its associate (*A. affinis?*) not only by the facial suture, but by the scarcely pronounced axis of the tail. And from *As. Powisii*, with which it might be confounded by casual observers, the want of any tail-furrows except obscure ones on the axis, and the very slight convexity of the glabella, will easily separate it. It grows to only half the size of that species.

Locality.—UPPER TREMADOC slate, under the Garth, near Portmadoc. (Mr. Homfray's cabinet. Railway, back of Penmorfa village; Tu-hwnt-i'r-bwlch near Portmadoc, &c. Mus. of Pract. Geol., and of Messrs. Ash and Homfray.

Asaphus radiatus, Salter.

Pl. 23, fig. 7.

Ogygia radiata, Salter in Appendix to Ray ed. of Burmeister, 125; *Isotelus laticostatus*, M'Coy (in part), Synopsis Woodw. Foss., Pl. 1 E., fig. 18, not 18 *a*; *Asaphus radiatus*, Salter, Palæont. Soc. Monograph Tril., pl. 18.

A. subplanus, obtuse ovatus, capite latissimo, glabellâ distinctâ. Thorax brevis. Cauda semicircularis, utrinque costis 7-8-brevibus radiata; axe abbreviato ⅔ caudæ solùm efficiente. Sulci laterales simplices, recti, breves, nec marginem attingentes. Fascia latissima valde striata.

This was for some time confounded by myself with the Swedish fossil *Ogygia dilatata*, as it has been by M'Coy with *Isotelus laticostatus*, Green, of North America. In identifying it with the latter fossil, Professor M'Coy had chiefly in view the large specimen which he has figured (l.c. 18 *a*) from the Llandeilo flags of Builth (Maen Goran). This he says agrees exactly in proportions with Green's species, and is certainly different from the Bala limestone fossil before us. His specimen is the most perfect we possess, and fell to my own hammer in a long and pleasant summer's work with Professor Sedgwick in 1844.

M'Coy describes and figures the entire form as obtusely oval; the cephalic shield rounded, about three times wider than long; the thorax shorter than the head, of eight slender segments; its axis rather less than two-thirds the width of the *pleuræ*, which are nearly straight, slightly bent downwards and backwards at the fulcrum, the *pygidium* nearly semicircular, its length more than half the width, and one third longer than the thorax. Axis rather convex, narrow; it tapers gradually to the somewhat prominent tip, which reaches less than two-thirds down the tail, and is annulated by about eight furrows, leaving a small terminal unlobed portion.

The side-furrows, including the front marginal one, are about eight or nine in the adult, (10 or 11 show in the young state!) and are shorter and shorter backwards, all simple, straight, or but a little sinuate; strong till they reach the broad, deeply striated, and flat or gently concave border, when they become faint and vanish. The five hinder ones scarcely reach half way to the margin. These minute details are necessary to distinguish the British species readily from such species as the *Og. dilatata*, which has duplicate, not simple, caudal ribs, bent near the end; and also from the *Asaphus nobilis*, Barrande, a Bohemian Caradoc species very like ours indeed in the tail characters (but with a longer and more slender axis), and a cephalic shield larger and longer in proportion.

The side-furrows of our species are rather crowded at their origin, so as to seem radiating, whence the name. In *A. nobilis* they are more parallel; and the ornament on the axis is greatly more prominent in the Bohemian form.

Locality.—CARADOC or Bala limestone, Rhiwlas, near Bala (Woodw. Mus. and Mus. of Pract. Geol.); also in Caradoc shale, Co. Louth, Ireland.

Asaphus Powisii, Murch.

Pl. 15.

Siluria, 2nd ed., pl. 2, fig. 2. *Isotelus Powisii*, M'Coy, Synopsis Woodw. Pal. foss., p. 170 (not of Portlock).

We have been able to figure this in a very perfect state from the neighbourhood of Bettws, N. Wales, and in an oblique compressed form from the cleaved slates of Dinas Mowddwy, N. Wales. Portlock's fossil is the *I. gigas.*

Locality.—CARADOC rocks, N. and S. Wales, Shropshire, Westmoreland.

Asaphus (Basilicus) tyrannus, Murch.

Pl. 13, figs. 1–5.

Decades Geol. Survey, No. 2, pl. 5; Siluria, 2nd ed., pl. 2, f. 1.

A truly characteristic species of the *Upper Llandeilo* age. Our figures are transferred from the steel plates of the Decades Geol. Survey, No. 2.

A. tyrannus is a local species. Though very like several foreign forms, it is restricted to the British area, not even ranging to Sweden, where the *A. heros*, Dalman, takes its place. Of all the sections of *Asaphus*, this one, *Basilicus*, comes nearest in habit to the *Ogygiæ*, from the whole of which, as well as from the intermediate genus *Niobe*, Ang., it is distinguished at once by the cleft labrum.

Locality.—UPPER LLANDEILO, Craig-y-glyn, and Craig-y-beri, near Llanarmon fach, in the Berwyn Mountains, the most northerly point in Wales attained by the Llandeilo *limestone*. All the Caradoc localities given for it are spurious.

Ogygia scutatrix, Salter.

Pl. 9, and pl. 8, fig. 8.

Siluria, 2nd ed., p. 53, Foss. 9, f. 1; Palæont. Soc. Monogr., 1865, pl. 17, f. 11–13.

O. septuncialis, fere rotunda (aut latissime elliptica) depressa. (Caput?) Thorax quam caudâ brevior, axe lato, pleuris longis, axin 1½ superantibus, profunde sulcatis, a fulcro (ultra dimidium posito) paullo deflexis. Cauda quam semicirculari latior; axi lato 8-9-annulato; limbo sulcis primariis 7-8 ad apices fractis; secondariis rectis profundis axin haud attingentibus.

The large size and round form of this fine species much recals that of *O. Desmaresti*, (*O. Brongniarti*, Rouault), well figured by the latter authority in the Bull. Soc. Geol. France, vol. vi., 2d. ser., pl. 1. From that species the less width of the axis, the straight (not curved) pleuræ, grooved nearly to their ends, distin-

guishes it. From *O. Edwardsii*, pl. 2, fig. 1, ib., the fewer joints of the tail, even in our much larger specimen, and the few lateral furrows, all of them duplicate, distinguishes it. The pleuræ too are curved in *O. Edwardsii*, which in very many respects resembles *O. Desmaresti*.

Our specimen may be altered in shape by the pressure accompanying cleavage; but in the figure some allowance is made for this. If not sufficiently so, still the form must have been a very wide and rounded one, and can scarcely ever have had the shape of the species next described, although evidently closely allied to it.

Locality.—UPPER TREMADOC ROCKS. Northern face of the Garth hill, at the mouth of the Traeth Bach, Merionethshire, in company with abundant specimens of *Angelina* and other trilobites and shells.

A specimen crushed in exactly the opposite direction, and so lengthened out instead of widened, is figured in Pl. 8, fig. 1. This specimen has the labrum of the usual shape in the genus, but rather more pointed than usual. We have also another specimen from the LOWER TREMADOC, W. of Penmorfa, on the Caernarvon Road.

O. peltata, n. sp. (*An O. Scutatrix?* var.)

Pl. 12, fig. 8.

Salter, Paleont. Soc. Monogr., pl. 17, f. 8–10, 1865.

O. modica; capite, thorace, caudâque æqualibus. Glabella lata, lævis, sulcis nullis. Thorax axi depresso, pleuris angustior, his usque ad apices falcatos nec decurvos planis, fulcro obsoleto. Cauda quam semicirculari longior; axi lato, 8-annulato; limbo sulcis primariis subrectis, secondariis abbreviatis.

From fragments in the black slate of St. David's Head, this fine species must have been nearly 4 inches long, and of a broad oval shape. The head, thorax, and tail are nearly of the same length, and the whole form is greatly flattened.

Head somewhat longer than a semicircle, with short broad head-spines, margined throughout, divided nearly equally into three parts, the glabella being as broad as the cheeks, parallel-sided, and without any distinct lobes.

The eyes are large, placed half way up the head. The neck-furrow distinct, that portion of it on the cheeks much nearer to the posterior margin than that beneath the glabella. Thorax with a wide axis, not however quite so wide as the pleuræ, and somewhat narrower behind. The rings are very flat, and scalloped out at their junction with the pleuræ, so that the axal furrows present a set of re-entering angles with concave arches between them.

The pleuræ are flat, their points short-falcate, and the pleural groove is sharp and sigmoid in its curve, reaching nearly to the tip.

Tail a semicircle, the axis occupying a quarter of the entire width, and tapering backwards. It is annulated by seven or eight furrows. The tip is blunt. The sides are radiated by eight strong grooves (including the upper or sub-marginal one), which are slightly bent downward near their ends, and are interlined by similar parallel secondary grooves, which start abruptly, as in *O. scutatrix*, from a point near, but not close to, the axis; a plain smooth margin forms the border of the tail, and the incurved under portion is narrow and closely striated.

The specimens described are all from St. David's Head, and appear to differ from the N. Welsh *O. scutatrix* in the following particulars:—More elongate form, flatter and more pointed pleuræ, tail with a narrower axis, and only one distinct set of lateral furrows. From *Barrandia Portlocki* and allied species the much greater length of the axis will easily distinguish the two species. They belong indeed to different genera. (See Palæontogr. Monogr. 1865.)

Locality.—LOWER LLANDEILO. Whitesand Bay, St. David's Head.

Ogygia Selwynii, Salter.

Pl. 9, figs. 2–6, and pl. 11 B, fig. 5.

REF.—Brit. Assoc., 1852, p. 57, &c.; Siluria, 2nd ed., Foss. 9, fig. 8, p. 53; Monograph Pal. Soc., 1865, pl. 17, figs. 1–7.

We have specimens from three localities. A caudal shield from Merionethshire, and a thorax and tail from South Caernarvonshire; to these the name is

intended to apply. And some larger specimens, parts of the head, and very complete caudal shields, &c., from Shropshire; these appear to be exactly the same species, and are described afterwards. Figs. 1, 2, 3, and 4.

Thorax and tail 10 lines long (the general form must have been a long-oval); thorax 9 lines broad, of eight narrow flattened segments, the axis well defined, gently convex, not quite two-thirds the width of the pleuræ. The latter are flat as far as the fulcrum, which is placed half way out, then bent down, the pleural groove very shallow, except beyond the fulcrum, where it is deeper. The tail is rather more than a semicircle, with a depressed border; it is smooth, the ribs being faint, and only on the upper part. The axis is distinct, narrow, tapering rather rapidly at first, then parallel, and ending with a prominent tip, just within the depressed border, at rather more than three-quarters the whole length; the upper part is annulated by about five faint ribs, the rest smooth; sides radiated above by seven furrows, of which the upper one is far the strongest; the lower part is smooth. The border is rather abruptly depressed; the incurved under portion reaches to the point of the axis.

Localities.—LOWER LLANDEILO. Fig. 1 at Hengwrt-uchaf, four miles north-east of Dolgelly; in the higher part of the igneous series (Professor Sedgwick and J. W. Salter, 1844). Figs. 2, 3, Llanfaelrhys, near Aberdaron, South Caernarvonshire. (Mus. P. Geology.)

Figs. 5 and 6, *Ogygia Selwynii*, var. *major*. Caudal shields more than a semicircle, 10 lines long by 16 broad. The axis is narrow, and tapers as in the last, but does not reach quite to three-quarters the length of the tail (in the Welsh specimens it reaches fully to that distance). It is annulated by six or seven furrows above, the upper one often the strongest, and the rest faint. The sides of the tail are marked by seven shallow short furrows, which do not reach to the depressed border, and the upper one of these also is the strongest. The incurved under portion is concentrically striate, and reaches to the tip of the axis, folding over it, and covered with concentric striæ. Head more pointed than a semicircle, an inch and a half broad, and often larger: we have been able to restore it from the parts preserved, but the sides are flattened more than our figure shows. The glabella distinct all round, depressed, gently clavate in front, but otherwise parallel-sided; marked very obscurely on the sides with one or two impressions, and having a faint central ridge near the base, and no distinct neck-furrow. The cheeks broader than the glabella, nearly flat; the large eyes placed rather less than half way up the head, and near the glabella. Margin indistinct, narrow in front of the glabella; broad on the cheeks, ending in a narrow spine posteriorly. The facial suture cuts the posterior margin more than half way out; in front it is marginal.

O. corndensis does not appear to differ much from ours in the head, except that the eyes are rather smaller and more forward, and the head spines reach to the tail; but the pleuræ are blunt-ended, deeply grooved, and strongly facetted for rolling. The axis of the tail is about the same length as in the Welch variety of our species, but the lateral furrows are strong, and indent the depressed border, while the incurved striated caudal fascia is not nearly so broad. All the furrows of the tail are much stronger, and the crust itself probably much thicker.

Locality.—LOWER LLANDEILO. White Grit Mine, near Shelve, Shropshire; associated with *Lingula, Ctenodonta, Theca,* and *Bellerophon*. It was also found by Sir R. I. Murchison at various localities nearer to the Stiper Stones, viz., in Mytton Dingle and at Lord's Hill, and is now common in cabinets.

Niobe, Angelin, 1852.

The genus _Niobe_ was formed by Professor Angelin to include those flattened species of _Asaphus_ which have the lobed glabella and blunt labrum of _Ogygia_, and the facetted obtuse pleuræ of _Asaphus_. _N._ (_Asaphus_) _frontalis_, Dalman, is the type.

***Niobe Homfrayi*, n. sp.**

Pl. 6, figs. 5–8.

Salter, Monogr. Brit. Tril. Paleont. Soc., 1865, pl. 22, figs. 3–12.

N. ovalis, depressa, lata, 3–4–uncialis; axe sub-plano, distincto, caudâ semicirculari semiradiato. Glabella genis æqualis, urceolata. Oculi ante medium

capitis positi. Anguli capitis obtusi. Labrum acutum. Cauda semicircularis, sulcis lateralibus 4–5, *abbreviatis, interlineatis.*

General shape a very broad oval, fully two-thirds as wide as long, depressed; the length between three and four inches. The axis is flattened, yet distinct throughout; wide and tapering from the broad urceolate glabella to the blunt tail-axis. The head is smooth, very little lobed, and the sides of the tail imperfectly radiated. The head is rather more than one third of the whole length, semicircular, with blunt outer angles, the glabella occupying one third the width of the head, urceolate, blunt and widest in front, then a little contracted, and thence widening again to the base, marked by a very distinct neck furrow. The glabella furrows are faint, four short ones on each side, somewhat radiating from the eye inwards, the lower one longest. The eye is very near the glabella, and placed more than half way up the head, semilunar. The facial suture reaches the edge immediately over the eye, curves boldly out beneath it, so as to leave but a third part of the posterior margin of the cheek outside it; it is marginal in front.

The body axis is broad, equal to the pleuræ in front, but narrower than those behind, and ornamented with arched striæ. The pleuræ are strongly facetted for rolling up, blunt, and rounded at their ends; the fulcrum close in to the axis in the front rings, and gradually further out till it reaches one fourth in the hinder ones. The pleural furrow is deep, but rather short.

The tail, a true semicircle, is somewhat flattened, and has a short broad axis reaching three-fourths the length of the tail, and about half as broad as the side portions, or a little more, marked by seven or eight distinct furrows nearly to the tip, which is prominent and bluntly pointed. The sides are scored by five short furrows, which (faintly interlined) only reach to the inner edge of the broad, flattened margin, and there stop abruptly. The margin is concentrically striate, of equal breadth all round. Young specimens (fig. 8) differ but little in proportion. The labrum is long and pointed, more so than in *Ogygia*, and has a concentric furrow near the margin, with a strong pair of indentations near the tip.

Locality.—LOWER TREMADOC SLATE.—Penmorfa Church, Tremadoc, and Castle Deudraeth, near Maentwrog, North Wales. Cab. of Mus. Pract. Geol., Mr. David Homfray and Mr. Ash.

A much narrower variety, probably a male specimen (as Mr. Ash suggests), is in that gentleman's cabinet. It furnished the sketch for the labrum.

Psilocephalus, n. g.

At first placed with *Asaphus*, (that convenient genus being a receptacle for a good many distinct forms.) I have not much doubt this will form a very distinct and well marked group. The small forward eye easily distinguishes it from *Nileus*, the subgroup of *Asaphus* which it most nearly resembles; and the same character, together with the eight grooved body rings, distinguish it from *Illænus*.

Psilocephalus innotatus, n. sp.

Pl. 6, figs. 9–12.

Salter, Palæont. Monogr. 1866, pl. 22, ined.

P. latè ovatus, lævis, sesquiuncialis; capite valde convexo, haud trilobo, quam caudâ semicirculari multo majori; pleuris 8 *planis.*

This neat and rather conspicuous form is the most abundant fossil in the Lower Tremadoc beds, in company with *Niobe Homfrayi*, which is a much more rare species. Scarcely an inch and a half long, and about three-quarters broad in the largest specimens, usually one inch long, convex, strongly trilobed in the body, more faintly so in the tail, and the subspherical head destitute of trilobation or axal lines; body rings eight. The general shape is a rather broad, blunt oval; the head considerably longer than the tail, semioval, blunt, very convex and smooth, with obtuse outer angles, near to which the facial suture takes its rise, running obliquely inwards to the front margin, which it cuts rather within than immediately over the eye. Eye very forward, fully two-thirds up the head, small. Glabella confused with the cheeks, not at all marked out, except below (as in *Illænus*); labrum? Body strongly trilobed; the axis narrower than the sides, and tapering backwards.

The pleuræ have square ends, are blunt, a good deal curved down from the fulcrum, which is at one fourth in front, and thence extending further and

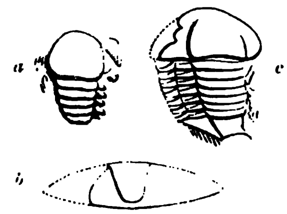
further outwards till it reaches one third in the hinder rings. The pleuræ are flat or very slightly concave as far as the fulcrum, thence sharply facetted and striated lengthwise. (The pleural groove only shows in its lozenge-shaped outward termination.) The tail axis is rather long, blunt, semicylindrical, reaching three-fourths down the tail; smooth as well as the convex sides, which have no flat or hollow margin along the striated border at all, nor any kind of furrows or ribs.

Locality.—In abundance all through the LOWER TREMADOC beds of Penmorfa and the neighbourhood of Borth and Moel-y-gest, *e.g.*, Borthwood, Tyn-y-llan, Tyddyn-llwyn farm, &c. The finest specimens were obtained in company with Mr. D. Homfray, and are in his cabinet or our own. Mr. Ash has also a fine series, and the species is now in many collections.

Psilocephalus inflatus, n. sp.

Woodcut 8.

Fig. 8.



P. bene trilobus, capite inflato, glabellâ distinctâ rotundâ, axe corporis prominulo, caudæ brevissimæ distinctissimo.

I give a woodcut of a small species, which, occurring at two places, appears to me to differ in specific character from the *P. innotatus*. It should have been included in the plate, had I perceived its full characters sooner. Head very convex; the glabella rounded, and separated by its convexity and by distinct furrows from the rest of the head. Position of eye? Body with a moderately broad, convex axis; also well distinguished from the somewhat convex pleuræ, the hinder ones of which are curved. I can only find seven body rings. The tail, if it belongs to the same species, is short, and has the axis not only convex, but short conical, and marked out clearly all round.

Locality.—In lower beds of the LOWER TREMADOC, north-west of Penmorfa, on the Caernarvon road (figs. *a*, *b*), and in the upper beds of the same lower series at Trwyn Cae Iago, west side of Portmadoc Harbour (*c*); also at Borthwood. (Mus. Pract. Geol.)

Illænopsis, n. genus.

Ovate, head very convex, with widely divergent axal furrows reaching to the front. Fixed cheeks large; free cheeks small; the eye placed close to the *front* margin; facial suture ending on the outer margin. Pleuræ pointed, grooved.

Illænopsis Thomsoni.

Pl. 11 B, fig. 1.

I must describe this form, though the pygidium supposed to belong to it may possibly belong to a different species: it is found in the same locality. In the head, the very forward position of the eyes is unlike that of any *Illænus* yet figured. It is true that the older *Illæni*, *I. arcturus*, Hall, and *I. clavifrons* of Billings, have the eye forward; but in none does it occur so forward, or so near to the glabella, as in this case. Mr. Billings does not describe the position of the eye in his *Illænus conifrons*, but from his figure it must be nearly in the same position as ours, and possibly that species may be an *Illænopsis*. *See* Geol. Canada, p. 151.

Of the thorax we have only two pleuræ, but these are quite different from those of *Illænus*, pointed and grooved; in *Illænus* they are blunt and grooveless. The pygidium supposed to belong to this (and there is the greatest probability it does so) is deeply trilobed; the axis narrow and prominent, reaching nearly three-fourths the length of the tail, and with the upper ring distinct.

Locality.—LOWER LLANDEILO. Bogmine, Shelve; in dark earthy shale.

Illænus Bowmanni, Salter.

Pl. 18, fig. 8.

Salter in Decade 2, Mem. Geol. Surv., *I. centrotus*, Portlock and M'Coy, not of Dalman.

One of the commonest of our Lower Silurian trilobites (Caradoc), yet not understood at all. It has a broader outline than the following, and the eye placed so far back as nearly to touch the hinder border.

Locality.—CARADOC.—Everywhere in Britain.

I. Davisii, Salter.

Pl. 18, fig. 9.

Decade 7, Geol. Survey, pl. 2.

Well distinguished by the proportions of head, glabella, and tail, the proportion of the eye, and other characters, from other *Caradoc* species. The characters are fully described in the memoir above quoted.

Locality.—CARADOC. N. Wales, chiefly Rhiwlas, W. of Bala, also S. Scotland, as in Peeblesshire.

Æglina grandis, Salter.

Pl. 12, fig. 11:

Siluria, 2d. ed. Foss 9, f. 6. Decades Geol. Survey, No. 7, Pl. 10, f. 8, and No. 11, Pl. 9, f. 7, 8.

Æ. ovalis, sesquiuncialis, depressa? glabellâ tuberculatâ; axe corporis angusto; caudâ lateribus unisulcatis.

Oval (rather depressed?), 1¾ inch long; head more than two-fifths the whole length, with a large glabella without lobes, covered with rather prominent tubercles. Eyes very large, as long as the head. Body of six rings, the axis narrower than in most of the species; broadest in front, contracted behind, where it scarcely equals the pleuræ in width. These are bent at the fulcrum, which is placed rather more than one-third out from the axis. The tail is semicircular, and has rather a long-conical axis of two joints, and one obscure lateral furrow.

The largest specimen appears to have the fulcrum further inwards, but agrees in other respects with the remaining specimens; at least it has the tubercular glabella, a character in which our species differs from all others. Of the two British species previously described, *Æ. mirabilis* has a parabolic and lobed smooth glabella. *Æ. major* has a wide body axis, and two lateral furrows in the tail. The fragment figured by us without a name in Decade VII., pl. 10, fig. 8, appears to be quite the same, but is possibly from a higher formation. All Barrande's species have a smooth glabella, and are very much smaller, except *Æ. speciosa*, which has a very broad axis and short marginal eyes.

Locality.—LOWER LLANDEILO. In black slate, Whitesand Bay, south side of St. David's Head, Pembrokeshire.

Æglina, sp., eye of.

Pl. 12, fig. 12.

Decades Geol. Surv., No. 11, Pl. 4 f. 6.

The large species just figured is by no means the largest *Æglina* known. M. Barrande has an enormous one from the Llandeilo rocks of Bohemia, and we here figure the eyes (no other part occurs with them) of a great species, probably seven or eight inches long, from the Upper Llandeilo flag. Contrary to the usual arrangement in the eye, the lenses are in quincunx, instead of hexagons. The eye alone measures half an inch in length! It is figured and described in the above decade.

Locality.—UPPER LLANDEILO FLAGS; Abereiddy Bay, Cardiganshire.

Æ. binodosa, Salter.

Pl. 11 B, fig. 3.

Siluria, 2d. ed., Foss. 8, p. 6. Decades Geol. Surv. No. 11, Pl. 4, f. 1–6.

Æ. lata, biuncialis et ultra, convexa; capite grandi, inflato, lævi; segmento thoracis tertio binodoso; caudâ triangulatâ profundè marginatâ.

One of the most marked species of the genus, and in great plenty in the black slate of one locality. It differs so markedly from all the other species, in the triangular tail with a prolonged axis, that it is unnecessary to compare it with any. It appears to have grown to as large a size as *Æ. grandis.*

Locality.—LOWER LLANDEILO. Cefn Gwynlle, in the district west of the Stiper Stones, Shropshire; in black slate, abundant. My friend Dr. A. Fritsch, of Prague, tells me he has found the same species in the lowest Llandeilo beds (*d* 1) of Prague. I think this is correct.

Æglina? caliginosa, n. sp.

Pl. 11 A., fig. 10.

Æ. uncialis et ultra, lata, ovalis. Caput semiovale; glabellâ omnino lævi, nec sulcatâ; oculis angustis. Thorax segmentis 5, *axe latissimo. Cauda semicircularis, axe angusto, tricostato; lateribus bisulcosis.*

An inch and a quarter long, and about an inch in breadth, judging from specimens compressed in both directions. The head is a little longer than the tail, the former semioval, the latter semicircular. And there are certainly only five body rings, which fact, however, would not of itself justify the creation of a new genus. It is better left in *Æglina*. *Æ. pachycephala*, a Bohemian species much like ours, has only five rings.

Head wide semioval, regularly convex. The glabella not at all distinguished from the fixed portion of the cheeks, nor marked by any glabellà furrows; the hinder angles a little prominent; the eyes (probably, for they are not preserved) narrow.

Body rings five, with an axis more than twice as broad as the pleuræ, and rather suddenly narrowing behind towards the last segment. The pleuræ increase proportionately in width, the front one being only one third the width of its axal lobe, the last one much more than half the width of the same portion. They are all obliquely truncate at their ends, and grooved throughout. The fulcrum is near the axal furrow. The tail is semicircular, with an abruptly conical short axis, of three rings; the two upper ones tolerably distinct; the third imperfect. The lateral furrows are very short, and only two show distinctly besides the uppermost one. The incurved under margin (caudal fascia) is narrow and equal all round.

There is no Bohemian species, except *E. pachycephala*, with which to compare it. And that species is so much narrower and more elongate, that there is no need to point out other distinctions. Like ours, it has only 5 rings. *E. oblongula*, Angelin, a Lower* Silurian species from Vestrogothia, is much more like ours, and were the axis broader I should not like to separate the two species. In that figure no ribs are shown on the tail. There are 5 body rings.

Locality.—LOWER LLANDEILO. Ty-obry, Garth, near Portmadoc. Our figure is from Mr. Homfray's Cabinet; but we have many specimens, some a little larger.

Trinuclidæ.

A small group, yet of very common occurrence. I do not know that we can safely include in it more than the three genera—*Trinucleus, Ampyx*, and *Dionide*. And in truth this last genus shows the relation of the group to the *Asaphidæ* through *Ogygia.*

Trinucleus Murchisoni, Salter.

Pl. 11 B., fig. 4.

Trinucl. Murch., Siluria, 2nd ed., p. 50, fig. 7.

T. semiuncialis, oblongus, haud quadratus, fronte radiatim punctato. Radii profundi, nonnullis brevioribus mixti. Caudu trigona, lateribus curvis, costisque brevibus binis.

A neat species, abundant in the black shales of the Shelve country. About half an inch long, with the lobes of the head tolerably equal in breadth, and only minutely granular (not pitted as in *T. fimbriatus*). The fringe is not very narrow, and of tolerably equal breadth along the front; the radii sunk, and

* Angelin gives the locality, Besstorp, in Vestrogothia, and quotes the species from Stratum E. (Wenlock). I cannot help thinking this must be a mistake, for the genus is so completely a Lower Silurian one. *Dionide*, see p. 321, is found there.

with a few interlining ones in front; the ears narrow, small. The tail is half as long as broad, triangular in outline, but apparently with curved sides from the sinuous outline of the bent portion. This is very broad, even for this genus, and is only oblique, not abruptly bent down. The axis, with many prominent ribs, is carried over it. The sides, however, which are concave, have only two or three short curved ribs, while in *T. fimbriatus* there are at least five straight ones which reach the margin. It is very like *T. fimbriatus*, from which it differs in several important particulars.

The shape is longer. The fimbriate border in front has interposed shorter rays, the body rings are broader and the tail longer, with a more curved outline, and with only two lateral curved ribs. The incurved fascia is not vertical, but very oblique, and the axis is continued over it.

LOWER LLANDEILO. Cefn Gwynlle; and other places near Shelve.

Trinucleus Sedgwicki, n. sp.

Pl. 12, fig. 9.

T. uncialis? latus, capite semicirculari reticulato-punctató, glabellá subpyriformi, genas vix superante, lateribus bisulcatis; fimbriá angustá, concava, punctis radiatis, in series 5-6, quorum duobus exterioribus majoribus in sulco positis, collocatis; reliquis minutis transversis, nonnullis irregularibus et ad latera confusis; angulis posticis haud dilatatis.

Of this species we have but a few specimens. It differs at once from the common *T. Gibbsii*, its associate, in the want of any facial line. It is more nearly like *T. Lloydii*, Decade 7, pl. 7, from which it differs by the glabella being extended a little into the fringe, and by not having any expanded angles to the head. The fringe, too, is narrower, and has more unequal puncta, the outer two rows being large and sunk in radiating furrows, the inner rows not strictly regular, and more in number than the outer rows. The surface of the head, too, is closely punctate. It is quite possible this and the next may be varieties of *T. fimbriatus*, but at present they must be kept distinct.

Locality.—S. side of St. David's Head; Cae-glyd, Manod Bach, near Ffestiniog. In the LOWER LLANDEILO or "Arenig" rocks.

Trinucleus Gibbsii, Salter.

Pl. 12, fig. 10 (somewhat enlarged).

T. Gibbsii, Siluria, 2nd ed., p. 53, Foss. 9, fig. 7.

As broad as long (excluding the long divergent head spines, which reach back beyond the pointed tail); fringe narrow, punctate in radiating rows.

The head is transverse, but squarer than usual in the genus, with a fringe border only wide in the central part, and considerably so,—the fringe widening here to meet the glabella, which is shorter than the cheeks, and having in its furrows at least four or five puncta; while round the cheek they are reduced to two, and only become three or four again at the small posterior triangular ears. The spines start abruptly, are but slightly curved, and diverge but little, so as not to make with each other and the head an angle greater than 50°. The glabella is not more than one quarter the width of the head, and is short-pyriform, very clavate and blunt in front, quite narrow and marked with two distinct side-furrows behind. Its base is particularly narrow, and the neck furrow strong. The cheeks are spherico-triangular, rather convex, and reticulate over all the space behind a very strong ridge which bisects them, occupying the place of the facial suture. This ridge is curved forward, so as to divide the cheeks into two very unequal portions; where the continuous neck furrow abuts upon this ridge, at the posterior angle, it becomes a deep and broad hollow, almost a pit; and a similar deep excavation is established at the junction of the ridge with the front margin of the glabella.

The body has six flat rings, as usual; and is as long as the head without including the fringe, and not quite so broad; it has an axis one quarter its breadth, and it tapers back to the tail piece, which is sharply triangular, and even pointed; its length is one third its width, the axis being therefore broader in proportion than in the body rings. Three or four ribs are seen on the axis,

which is fusiform, not conical, and extends to the very apex. No side ribs, the lateral portions of the tail being quite flat and smooth.

Locality.—LOWER LLANDEILO. S. side of St. David's Head.

Trinucleus concentricus, Eaton.

Pl. 19, fig. 4.

T. Caractaci, Sil. System. *T. concentricus* of Eaton, 1832, and now of most authors.

We have repeated the generalized figure of this common fossil, which was given in the Memoirs of the Geol. Survey, vol. ii., pt. 1. And the peculiarities of the very simple fringe are given in fig. 4 a. It is remarkable for its simple flat expansion; a single keel on its lower edge, behind the two front rows of pores, alone breaking the uniformity of its shape. In most other species there is some variety in the ornamentation of the fringe. Either the pores are sunk in radiating furrows, as in *T. fimbriatus*, or they are enlarged at the outer angles as in *T. favus*, or the fringe is curved suddenly down as in *T. seticornis*, or concave as in *T. Lloydii*, or doubly convex as in some French forms.

In this fossil, as in the cognate forms, *T. Goldfussii* and *T. ornatus* of Bohemia, the fringe is flat above, and of nearly regular width throughout. But it is subject to variations in proportion, which variations are fully discussed in Decade 7 of the Geol. Survey.

Locality.—CARADOC rocks of Britain everywhere. UPPER LLANDOVERY; Shropshire, very rare, but certainly present (Lightbody and Salter.)

Trinucleus favus, n. sp.

Pl. 13, fig. 9.

T. concentricus, var. *favus*, Salter in Memoirs Geol. Survey, vol ii., pt. 1, pl. 9, fig. 3, and in Decade 7, pl. 7.

T. modicus depressus glaber, capite quadrangulo, fimbriâ latâ, ad angulos rectos externos favosâ. Glabella parva. Spinæ genales divaricatæ.

I think it cannot be wrong to recognize this extraordinary form as a distinct species. It is extremely common in S. Wales, always in Llandeilo rocks, and is also found in the patch of Llandeilo limestone, which appears so strangely introduced into the network of faults on the east of the Berwyn Mountains, N. Wales.

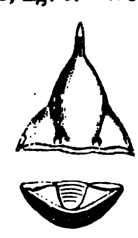
I cannot believe, with my friends Prof. Wyville Thomson and M. de Barrande, that the facial suture in *Trinucleus* runs round the margin. I conceive that its course is marked out by the obscure line which runs obliquely across the glabella, and that the fringe is simply a variation of marginal ornament, in fact a set of coalesced marginal spines. Moreover, the indications of eyes in some forms of *Trinucleus* (or *Tretaspis*, *T. seticornis*, &c.) favours this view. It is a fair subject for discussion.

Locality.—UPPER LLANDEILO. N. and S. Wales.

Ampyx tumidus, Forbes.

Pl. 23, fig. 6. Woodcut 9.

Fig. 9.



A. tumidus, Forbes in Decade 2, Mem. Geol. Survey, pl. 10, p. 4.

A. capite elongato brevispinoso, caudâ brevissimâ. Glabella maxima, obtusa, carinata, postice convexa, paullulum contracta, anticè in spinam brevem sulcatam, haud abruptè producta. Genæ parvæ, vix dimidium glabellæ attingentes, sulco postico distincto; spinis? Cauda bis quam latâ brevior, omnino lævis, nisi axe lato sulcato, lateribus margini deflexo latissimo.

Though only indicated by Forbes in the Decade above quoted, the species is a distinct one in a genus remarkable for the number and similarity of its species.

We have but the head and caudal shield, in plenty. The former, as may be seen by the lengthy diagnosis given above, is greatly elongate in front even for this genus, *i.e.*, the body of the glabella itself is lengthened out, and is also broad; it is most convex behind, where it is but little contracted, and furnished with a single short lateral lobe, not well shown in our figure; but these lobes are less approximate than in the *Amp.* (*Raphiophorus*) *depressus* of Angelin, a Lower Silurian Swedish form, most like our species of any, yet with the glabella far too short, and cheeks and pygidium too long. Were it not for the long pygidium figured with it, I might have referred ours to *A.* (*Lonchodomas*) *domatus*, Angelin. I think M. Angelin has not shown good grounds for his mode of subdividing the genus.

As for *Ampyx tumidus*, "It is nearly allied," says Forbes, "to *A. rostratus*, Sars., but differs in having much smaller cheeks in proportion to the glabella, which is even more produced than in the *A. rostratus*, and exceedingly tumid. The cheeks in the species to which I have compared it are beyond the middle of the glabella; in the British form never so far as that part. The neck lobe, too, of the latter is narrow; and the tail, though similar in sculpture, is much shorter and wider." Professor Forbes also compares it with *A. Bruckneri* (Boll, in Dunker and Meyer's Palæontographica, 1 Band., t. 17, fig. 8), a species with a carinate glabella; with *A. Portlockii*, Barr., which has a contracted glabella, while ours is elongate; and, lastly, with *A. Bohemicus*, Corda, a form with wide glabella, minute tail, and no rings on the axis.

Locality.—CARADOC limestone, Rhiwlas, Bala.

Ampyx prænuntius, n. sp.

Pl. 8, fig. 5.

Ampyx (***proavus majorum stirps***), ***minutus. Glabella brevis, haud ad marginem angustum producta, sulcis obliquis lateralibus. Axis segmentis 6. Cauda subtriangularis costulata, axi abbreviato.***

(*Specimina tria compressa in museo cl. F. Ash tantum vidi*).

A minute species, which has the peculiarity of showing only a semioval, not triangular head, with a very short glabella, not elevated in front, and with a very oblique lateral furrow on each side. It is not clavate or gibbous, only convex forwards, and not at all produced beyond the slightly angular front margin, which has a narrow convex rim all round it.

The body is very little different from that of other species, of six rings, with a rather wide convex axis. The tail is only sub-triangular, and somewhat rounded, with a short convex axis, and two or three ribs on the sides.

We have only seen three specimens; they are on a single slab, and were detected by the keen eye of Mr. F. Ash. *A. prænuntius* is unquestionably the oldest species of the genus yet known.

Locality.—UPPER TREMADOC. Pen-y-clogwyn, Tremadoc.

Dionide atra, n. sp.

Pl. 11*a*., fig. 9.

D. maxima. Cauda plana triangularis, ¾ unciæ lata, et longa; axe haud convexo, angustissimo, longo, 20-annulato; lateribus subconcavis; sulcis obliquis 20, ad medium retrorsùm fractis nec marginem attingentibus, per dimidium interlineatis.

We have only the caudal portion; and yet, so characteristic is this portion, that there can be little doubt of the genus. It fell to my own lot to disinter the first specimens, when searching the dark slates at the farm of *Ty Obry*, near Garth; and our Tremadoc friends appear as yet to have discovered no more of this fine species, which is as distinct from either the Bohemian form *D. formosa*, or the Swedish *D. euglypta* (from Besstorp*) as we could wish. From both species the extremely narrow axis of the tail separates it.

Length and width of the flat triangular caudal shield about three-quarters of an inch, the extremity rounded, not acute; the long thin-pointed axis nearly

* Clearly this is a Lower Silurian locality, and therefore *Æglina oblongula* of Angelin, found with it, is also Lower Silurian. *Æglina* is not a primordial fossil.

reaching to the end, regularly conical, acute, not widening above, where it is certainly not one third the width of the side obe (while in the other species it is nearly half its width). It is annulated closely by about 20 distinct rings, and by more imperfect ones. The side lobes, which are slightly concave round the margin, have 19 or 20 oblique furrows which are abruptly bent down (*fracti*) at about half way out, and remain of the same strength nearly to the margin, which is quite plain, and apparently not at all striated concentrically. The ribs are interlined for the first half only, and the appearance thus given is that of a great multitude of ribs. Indeed there is no genus, except *Encrinurus*, which shows so many on the axis, and none at all which has them so numerous upon the sides.

Locality.—LOWER LLANDEILO. Ty-obry, in dark slate. (M. P. Geology).

Cheiruridæ.

We include in this the following groups:—*Cheirurus* and its subgenera; *Sphærexochus*; *Staurocephalus, Deiphon*; *Encrinurus, Cybele.*

Cheirurus Frederici, n. sp.

Pl. 8, fig. 1–3, and Woodcut 10.

Paleontogr. Soc. Monogr. Brit. Tril., Salter, pl. 5, figs. 18–21.

C. (Eccoptochile) uncialis et ultra. Glabella oblonga parallela, seu anticè angustior, sulcis distinctis radiatis, lobo antico parvo trigono. Genæ punctulatæ. Pleurarum sulci simplices exarati, apices longispinosi. Cauda major, 6-spinosa, spinis longis, rectis, subparallelis.

This Trilobite, only found as yet in the upper part of the Tremadoc slates, is a member of a genus more characteristic of higher beds (Lower Silurian). There cannot be much doubt about the genus, unless it may be referable to *Placoparia*, which has not, so far as known, the punctate cheeks visible in this specimen, and has nodular, not furrowed, pleuræ. *Eccoptochile*, Corda, is the nearest in character; and the fine species, *E. Sedgwicki*, described by M'Coy, is the only British species we have to compare it with. From that fossil the closely punctate cheeks and parallel-sided glabella greatly distinguishes it, and there are some other points of difference in the elongated pointed spines and deep simple pleural furrows of the body rings and tail.

Description.—Occasionally as much as 3½ inches long, and rather wide (all our specimens are much compressed). The head is wide, semicircular, or less; the outer cheeks, occupying the greater part of the head, are strongly punctate, margined all round by a continuous furrow, and produced into a long head spine,—the border smooth. The eye very far forward, as in *E. Sedgwicki*, and the facial suture rising so high as to cut the outer margin much in advance of the middle of the head, separating a very small free cheek. The glabella is not nearly so wide as the cheeks; it is parallel-sided, apparently not much longer than broad, and has the furrows very distinctly marked. These are three on each side, and rather deep, all straight and inclined a little upwards; the front ones especially, so as to have a radiate look. They reach more than one-third across the glabella, and thus leave but a narrow space down the centre. The front lobe, marked out by the two converging front furrows, is a wide triangle, and does not occupy more than a third of the length of the glabella. The surface is granulated, not punctate.

Thorax, in one tolerably perfect specimen in Mr. Homfray's cabinet, apparently composed of only 11 flat rings, of which the axis is not so wide as the pleuræ; these last are convex and *deeply grooved along the middle*, almost to the ends, which are produced into a long sharp spine, bent backward in all the segments, but most so in the posterior ones, in which the spines are fully equal to the length of the pleuræ themselves. If the thorax has 11 rings, the tail, which can hardly be distinguished from it, appears to have only four or five joints on the axis, and three short pleural lobes on each side, which are grooved throughout as strongly as and like the pleuræ of the body rings.

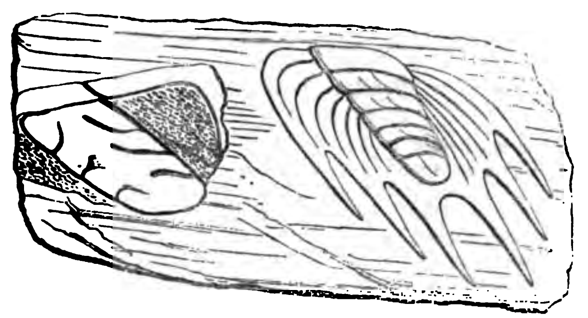
C. (E.) Sedgwicki, according to M'Coy's figures, has a much more complex tail. But the resemblance is very close, except in the number of tail spines, to such species as *C. Eryx*, Billings,* from the Quebec limestones, and I know no other with which it can be directly compared.

* Canadian Naturalist and Geologist, vol. v., p. 322.

A larger specimen, however, found by Mr. Homfray since this description was written, has six distinct joints to the axis, besides the terminal one, which is small, and three pointed pleuræ on each side, each about as long as the limb is broad,—and directed backwards, not much outwards. It is here figured: the specimen is in Mr. Homfray's cabinet.

The species is named after Mr. Frederick Ash, of Portmadoc, to whose services with regard to the geology of this part of N. Wales such frequent references have been made.

Fig. 10.



Cheirurus Frederici, distorted specimen.

Locality.—UPPER TREMADOC slate. Garth, Tremadoc. (Mr. Homfray's cabinet.)

Cheirurus juvenis, Salter.

Pl. 18, figs. 1, 2.

Cheirurus clavifrons, Salter and M'Coy, not of Dalman. *C. juvenis*, Salter, Mem. Geol. Survey, vol. ii., pt. 1, pl. 7, figs. 1–3; Decades Geol. Survey, No. 7, p. 12. Paleont. Soc. Monogr. 1864, Pl. 5, f. 9–12.

The reader may consult the rather full descriptions above given, in which he will see the errors myself and others have committed, in the reference of one of the common Caradoc fossils of the British and Scandinavian area.

It does not appear to range to America, and certainly does not cross the British Channel into the Lusitanian province.

Locality.—CARADOC. Bala, N. Wales; Westmoreland; Ireland.

Cheirurus octolobatus, M'Coy.

Pl. 18, fig. 3.

C. clavifrons, Dalm.?, Salter, Mem. Geol. Survey, l.c., pl. 7, fig. 3. *C. octolobatus*, M'Coy, Woodw. Pal. foss., t. 1 G., fig. 10; Salter, Paleont. Monogr. B. Tril. pl. 5, fig. 13, 14.

A small species, of which we formerly only knew the caudal portion. It has lately been figured perfect; it had a globular glabella and a truncate 8-spined tail.

Locality.—CARADOC. Bala.

C. bimucronatus, Murch.

Pl. 18, figs. 4–6, and var. fig. 7.

Sil. System, pl. 14, figs. 8, 9; Salter, Decade 7, Geol. Survey, pl. 2; Paleont. Monogr., pl. 6, figs. 9–18.

We have reproduced here the principal figures of this really large and very common trilobite, which ranges from the CARADOC to the LUDLOW rocks inclusive, over the British isles. Some of the finest specimens we have seen were found in Caradoc limestones, Kildare, and also at Sholes Hook, Pembrokeshire (fig. 5). The fossil becomes smaller, though still abundant, in Wenlock rocks (fig. 4–6), and in more sandy strata (it loves limestone best) assumes occasionally an extra prong to the caudal shield (fig. 7).

Encrinurus sexcostatus, Salter.

Pl. 19, figs. 5, 6.

Decades Geol. Surv. 7, pl. 4, figs. 1-11 (*Zethus*, M'Coy in Pal. foss. Woodw. Mus.), *Cybele sexcostata*, Salter, Mem. Geol. Surv., vol. ii., pt. i., pl. 8, fig. 10 (only).

An interesting Lower Silurian form of a genus far more common in Upper Silurian rocks. The present species is not unfrequent at Bala, in N. Wales, and Haverfordwest, in Pembrokeshire; but I do not know it in other localities. It is remarkable in the genus for the bluntness of the tail, and the small size of the tuberculation on the head. The eyes too do not appear to have been so large and prominent as usual in *Encrinurus*.

Locality.—CARADOC. Bala, &c., N. Wales; Shoalshook, &c., near Haverfordwest, S. Wales.

Cybele verrucosa, Dalm.

Pl. 19, fig. 7, head only.

Part of *Cybele sexcostata*, Salter, in Mem. Geol. Survey, vol. ii., pt. 2, pl. 8, fig. 9 (only). *C. verrucosa*, id., in Decade 7, pl. 4, p. 4. *Cybele*, Lovën. *Atractopyge*, Hall and Corda. *Zethus*, M'Coy.

In the work above quoted, I have figured this as the head of *Encrinurus* (*Cybele*) *sexcostatus*, but we had not then found the perfect animal. I corrected this in the Decade above quoted. For Angelin's complete figure of the *Cybele verrucosa* shows how very near that genus approaches, in some of its species, to the genus *Encrinurus*. There is the same clavate shape of the glabella, a similar set of furrows on it, viz., 4 distinct pits on either side, and the same clavate eyes as in *Encrinurus*. But there are 12 rings in *Cybele*; *C. bellatula* (*Calym.* of Dalm.) has certainly 12*, and the 6th ring in this species has a decided protuberance at the end, showing a tendency towards the fuller development of spines on the hinder segments of *Zethus*. All this differs from the Russian species described by Pander and Volborth as *Zethus verrucosus*, in which the glabella is not clavate, and the hinder pleuræ only are abruptly lengthened out.

Zethus bellatulus (*Calymene bellatula*), Dalman, however, sent us by Professor Volborth, has the shape of *C. verrucosa*, and I should propose, therefore, to keep these in the genus or subgenus *Cybele*, distinguishing it from *Encrinurus* by the number of segments (12), which in the principal species, *C. verrucosa*, are all lengthened out into long spines.

I retain the genus *Zethus*, only because the name is extant, and the species *Z. verrucosus*, Pander, fully described and figured by the careful Volborth; for *Zethus* was founded chiefly on a glabella of one of the *Cheiruri* (see Decade 7, pl. 4, p. 1), and *Cryptonymus* must, I think, be rejected entirely. It was originally intended for certain *Asaphi* by Eichwald, who afterwards, seeing his mistake, endeavoured to restrict it in 1840 to the tuberculate species now called *Encrinurus*. But Emmrich appears to have neglected this, and sufficiently indicated the genus *Encrinurus* in his scientific essay, 1845; M'Coy adopted and described it in 1846, since when the genus has been universally adopted. No good would be gained by reverting to the appellation *Cryptonymus*, and the name itself is objectionable in many respects. It may stand for a subgenus of *Asaphus*, as Angelin has already proposed.

Lichadæ.

Perhaps if we include in this abnormal group the genus *Lichas* and its subgenera, we shall be going as far as our materials permit us at present to do.

Lichas laxatus, M'Coy.

Pl. 19, figs. 1, 2, 3.

L. laxatus and *Calym. forcipata*, M'Coy, Synopsis Sil. foss. Ireland, t. 4. *L. laxatus*, Salter, Memoirs Geol. Surv., vol. ii., pt. 1, pl. 8, fig. 4-6.

Locality.—CARADOC. A fine species, very common in N. and S. Wales.

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* I should certainly prefer to regard *Cybele* as thus defined, viz., *C. bellatula*, *C. verrucosa*, as a sub-genus only of *Encrinurus*. The *Zethus verrucosus*, Pander, is quite a different fossil, and may fitly become the type of another sub-genus or genus, as above said.

Calymenidæ.

Calymene, the most beautiful form in the whole order, and *Homalonotus*, its anomalous ally, are found wherever Silurian rocks occur. It is probable that both of these genera transgress a little the upper limit of the Silurian system. *Homalonotus* certainly does. And it is certain that they begin with its lowest zones immediately over the primordial series.

Calymene.

Perhaps one of the most typical forms of Trilobite, and differing from all other genera in having the surface of the eye of soft texture.

The species differ only in slight particulars, at least in the larger part of the 20 or 25 kinds known. Some, however, have marked and distinguishing characters. The common *C. Blumenbachii* is at once the most widely spread and the longest lived; for it is known both in the Lower and Upper Silurian of Europe and America. I believe it has been divided into several forms, which cannot claim more than the rank of subspecies, as they pass by slight gradations into forms which no author has yet thought it right to separate from the type species. I shall therefore describe the *Calymene cambrensis* and *C. brevicapitata*, as varieties or subspecies only; they are recognizable forms. And if any should choose rather to regard them as species, their relative value is still the same.

I have given a plate of various species of this genus (pl. 17), ascending from the Llandeilo to the topmost beds of the Lower Silurian, in order to show the gradations between the so-called species in the Caradoc and Llandovery beds, and the real distinction between these and the Llandeilo species. The genus began with the Lower Llandeilo, and continued to the close of the Silurian system, the bounds of which, as above said, it only slightly transgresses.

The grouping of the species is as follows, in Britain :—

Lower Llandeilo (Arenig group) -	*C. parvifrons.*
Upper Llandeilo - - -	*C. duplicata, C. cambrensis, C. Tristani.*
Caradoc - - - -	*C. Blumenbachii, C. senaria.*
Lower Llandovery - -	*C. Blumenbachii.*
Upper Llandovery (May Hill group)	*C. Blumenbachii.*
Wenlock - - - -	*C. Blumenbachii, C. tuberculosa.*
Ludlow - - - -	*C. Blumenbachii.*

It will be seen, therefore, that while other species are short-lived, the common *C. Blumenbachii* or Dudley Trilobite has lived through a variety of conditions; hence it has varied much. And I consider the *C. cambrensis* and *C. senaria* sub-species only, as there are scarcely any tangible differences except those of proportion; hence the British species would be only four.

C. parvifrons and *C. duplicata* are sufficiently distinct from all.

Calymene parvifrons, n. sp.

Pl. 12, fig. 3.

C. parvifrons, Salter, Appendix, Pal. Foss. Woodw. Mus., 1851, pl. 1 F., fig. 7; Paleontograph. Trans. Monog. Trilob., 1865, pl. 9, figs. 25-28.

C. biuncialis et ultra, modicè convexa, sublævis; capite subtrigono, fronte valde productá, convexá, fere gibbá. Glabella angusta, brevissima. Genæ convexæ, oculis remotis, subcentralibus. Cauda lata, axi convexo, lateribus curvatis, costis per totum interlineatis.

About 2 inches long, the head subtriangular, and with a much produced front, equal in length to the glabella, which is about half that of the whole head. The glabella is short, parabolic, much narrower than the cheeks, which are convex, smooth, and have the eyes subcentral. The axis of the body is convex, narrower than the sides. The tail is wider than long, with a convex narrow axis, more prominent towards the tip, and the sides excessively convex and curved down, with five ribs, fully interlined from near their origin.

This is sufficiently distinguished by the very small size of the glabella; and as it is fully described in my monograph just published, need not be treated of more fully here. The *C. duplicata* is nearer than most, but has far too

narrow an axis and too flat a form; moreover the shape of the glabella is much narrower.

Localities.—LOWER LLANDEILO. Tai-hirion, on the Bala road, west of Arenig mountain (Coll. by Prof. Sedgwick and J. W. Salter). Under Manod Bach, Ffestiniog (Coll. J. W. Salter, 1853); Ty-obry, Penrhyn, Tremadoc; west of Stiper Stones, Shropshire, abundant.

Calymene Blumenbachii, Auctorum.

Pl. 17, figs. 1–7.

C. spectabilis, Angelin, Pal. Suec., t. 19, fig. 5. *C. Blumenbachii.* See Monog. Brit. Tril., Pal. Soc., pl. 8.

Typical specimens of this common fossil have the axis very broad and convex, the sides being curved and steeply bent down from the fulcral point. The glabella is also very wide and blunt in front, and scarcely any space divides it from the thickened but not produced front margin. The granulation too, especially of the head, is coarse and unequal.

The tail, too, follows the character of the thorax, and is convex, with short triangular sides. There are about seven distinct rings on the axis, and five forked lateral ribs, and the sides of the tail slope quickly away from the axis.

In our fig. 1–4 we have but little departure from these type characters. The front margin is not quite close to the glabella, and is somewhat more elevated. The body rings do not bend down so steeply, and in like manner the sides of the tail are more curved outward, so that it presents a more semicircular and less triangular outline.

These are only slight differences, yet they are such as exactly lead on to the greater variations observable in the var. *Caractaci*, and thence to *C. senaria.*

Our fig. 1–4 is from Lower Llandovery rock. The same form has been figured from the CARADOC of Ireland.

C. Blumenbachii. var. *brevicapitata* (or *Caractaci*).

Pl. 17, fig. 9.

SYN.—*C. brevicapitata*, Portlock, Geol. Rep., pl. 3, fig. 3.

Salter, Mem. Geol. Surv., vol. i., pt. 1, pl. 11, figs. 1, 2; *C. forcipata*, M'Coy, Sil. Foss. Irel., pl. 4, fig. 14, head only. *C. senaria*, Salter, Monog. Brit. Trilob., pl. 9, fig. 3–5. *C. brevicapitata*, Portlock's Report, second variety (*C. senaria* Conrad, Ann. Geol. Rep. N. York, p. 49, 1841). Salter, Mem. Geol. S. l. c., pl. 17, figs. 10–12.

In these varieties or species the glabella narrows more in front, yet is not truly triangular, except in the second variety, which I suspect to be a good subspecies. It is the *C. senaria* of Conrad, as above quoted, and is the more common. In the event of considering this a distinct form, it would be better to suppress the term *brevicapitata*, and replace it by the term *C. Blum. var. Caractaci*; as Portlock evidently intended the form with the shorter glabella. I have done this in the Monog. of Brit. Trilobites, above quoted. The front is produced and recurved, the margin not thickened or appressed against it, but projecting forwards. In the second variety the general shape of the head is triangular (the specimens figured by Portlock being only accidentally shortened by pressure). The axis is broad, and the sides of the tail curve more outwards than in the typical variety, and less than in the next described one, *C. cambrensis.* The coarse granulation of the surface is absent too, as in that variety.

C. parvula of Barrande is much like *C. brevicapitata* (or *C. senaria*) in shape, and I once thought it must be identical. Good specimens of the former, however, show a depressed glabella with shallow straight furrows, and a ridged front. It is altogether distinct.

Localities.—CARADOC rocks of Shropshire (figs. 7–9); of Bala and North Wales (figs. 11, 12); of Tyrone (fig. 10).

C. Blumenbachii, var. *Cambrensis.*

Pl. 17, figs. 13, 14.

C. brevicapitata (part), Salter, Mem. Geol. Survey, vol. ii., Part 1, pl. 11, figs. 3–5 (not 1, 2). Monogr. Brit. Trilob., 1865, pl. 9, figs. 12–14.

C. modica elongata, alutacea, glabellâ brevi, caudâ incurvâ. Frons producta subrecta. Glabella trigona, lobis utrinque binis, tertio obsoleto. Cauda axe angusto; lateribus valde curvis multisulcatis, sulcis binis.

This variety, or species, for it may be so considered very justly, though hitherto confounded by me with *C. brevicapitata*, differs in the following particulars:—

The glabella has only two distinct lobes, the upper lobe being minute and all but obsolete, thus (as in *C. pulchra*, Barr.) giving a "*fleur de lis*" appearance to the glabella. The front margin projects straight out, and it is not at all recurved. The general surface is finely granular.

The tail differs still more from the typical form (which has sloping sides and only 5 partially forked ribs). The sides in *C. cambrensis* are greatly curved, see fig. 5 in the above plate.

The distance, so to speak, between the variety here called *C. cambrensis* and the Caradoc variety, *C. brevicapitata* or *senaria*, is more considerable than between this last and the ordinary type; or rather the short interval is not bridged over by known connecting varieties. I prefer to retain it as a variety or subspecies for the present.

Locality.—UPPER LLANDEILO. Throughout South Wales, abundant.

The *Calymene parvifrons* above described has a still shorter glabella, and its front so much produced that it cannot be properly identified with any of the varieties of *C. Blumenbachii*. But even this is not so remote a form as the *Cal. duplicata*, a fossil which occurs with the *C. cambrensis* in the Llandeilo rocks, and which is next described.

[*C. Blumenbachii* seems indifferent to its habitat, on sand, in mud, occasionally in limestone, and, to judge from its wide range and its associates, it must have lived at various depths of water. *C. parvifrons*, on the other hand, has only yet been found in beds which have evidently been formed in shallow water; and *C. duplicata* is found only in black shale, and is possibly a deeper-sea form.]

C. duplicata, Murch.

Pl. 17, figs. 15, 20.

Salter in Siluria, 2nd ed., pl. 3, f. 6. Monog. Brit. Trilob., 1865, pl. 9, figs. 19–24.

C. sesquiuncialis, punctata, depressa, fronte vix productâ. Glabella parallela, longa. Oculi antici. Axis corporis angustus, caudæ longus præangustus, nec quartam latitudinis efficiens. Costæ interlineatæ.

An inch and a quarter long, and about seven-tenths broad, with a scarcely produced front, not above one third the length of the glabella; a very narrow axis, and a many-ribbed tail.

The glabella is rather parallel-sided than parabolic, one fourth only the width of the head (in the ♀ form broader), with three well-marked lateral lobes, the lowest not greatly projecting beyond the others, depressed, not rising above the level of the broad gently convex cheeks, on which the small eye is placed very forward, and half the width of the glabella from it. The neck-furrow is sharp, the axal furrows narrow and deep; the surface of the head is finely granular.

The body has a very narrow, rather convex axis;—in some specimens less than a fourth the width of the whole. The pleuræ quite flat, as far as, and beyond the fulcrum, then curved abruptly down. The pleural groove is sharp and narrow, the fulcrum remote in front, and nearly at one half behind. The tail is semioval, with a very narrow long axis, all but reaching the margin. It is long-conical, marked by nine or ten ribs, and is so narrow as not to occupy more than one-fifth the whole width of the depressed caudal shield. The side lobes have seven curved furrows, interlined throughout by shallower lines.

Localities.—UPPER LLANDEILO. Builth, abundant; Abereiddy Bay, Pembrokeshire.

Homalonotus bisulcatus, Salter.

Pl. 16, figs. 1–8.

H. bisulcatus, Appendix Pal. foss. Woodw. Mus., Pl. 1 G., figs. 24–31. Monog. Brit. Trilob., 1865, pl. 10, figs. 2–9.

A fine species, highly characteristic of the Caradoc sandstone of Britain, and described rather fully in the works above quoted.

Localities.—Shropshire and Wales, everywhere in CARADOC rocks; but found rarely in LLANDEILO, and even in LOWER LLANDOVERY beds.

H. bisulcatus, Salter ?

Pl. 11 *a*, fig. 8.

Although very imperfect, this specimen clearly represents the species above quoted, or at least there is no appreciable difference between crushed specimens of one and the other.

Locality.—LOWER LLANDEILO. Ty-obry, near Garth, Portmadoc, in black slate; also W. of Tremadoc (Prof. Sedgwick's coll., 1857).

Homalonotus rudis, Salter.

Pl. 16, figs. 9–11.

Synopsis, Pal. foss. Woodw. Mus., Pl. 1 E, fig. 20. Monogr. Brit. Trilob., 1865, pl. 10, figs. 12–14.

This also has been pretty fully described, as above. I have since found good specimens of the caudal portion in the fine yellowish grits of Cressage, Shropshire, the surface of which is finely tubercular, and the axis faintly nodular. These specimens show also that the lower furrows of the tail are as strong as the front one in this species: they are far less conspicuous in the kindred species *H. bisulcatus*. Moreover *H. rudis* is strongly trilobate; while the other follows the general form of the genus, and is related to numerous species of so-called *Trimerus* in the American rocks. *H. Brongniartii*, from the sandstone of May, Normandy, and lately described from S. Devon, is an extreme example of the simpler form of the genus. Its caudal edge is much incurved, and the species, like all other Normandy fossils, is well distinct from the British forms.

Localities.—Fig. 11 from the CARADOC or BALA rocks of Shropshire, near Cressage. Figs. 9–10 from near Bala, N. Wales.

Bryozoa.

Graptolites.

I have but one or two new species to describe, yet cannot pass over this opportunity of making a few remarks on a group which is most important as a Silurian index, and is vastly more populous in species and genera than was till lately believed. The family of *Graptolitidæ* is now exciting renewed attention. Barrande has, as usual, been in the advance with his full descriptions and exact figures. Professor M'Coy first defined the genera, Geinitz has endeavoured to systematize the nomenclature, and Professor Hall's work on America gave us many new forms. But the discoveries of the latter author, and of Sir W. Logan in Canada, have thrown an entirely new light on the extent to which the members of the group vary in shape, size, and complexity of form. And assuredly we are yet but little nearer to their true alliances than we were after the first memoir by Bœck, when he referred them to the *Alcyonarian Polypes*.

My own belief is that they are *Polyzoa*. I think Professor Huxley first suggested the resemblance of the disk-bearing forms to *Defrancia*. And I endeavoured from another point of view to bring them into comparison with the *Palæozoic Fenestellæ*, by describing *Graptopora* as a connecting genus.* But another interpretation may be given to the forms and structures of the group, and their reference to *Sertulariadæ* has satisfied both Professors M'Coy and Wyville Thompson.

The point I would chiefly call attention to is that there is a complete series of forms, from the very simplest up to the most compound, in this remarkable family. Sir W. Logan's discoveries only complete what was evident enough before, and it is with something like astonishment I find Professor Hall contending that the branched and dichotomising *Graptolites* are the only perfect specimens, and that all or nearly all the species which have the cells on one side only of an axis, must be imperfect specimens of this general form. Professor Hall has repeated this opinion again and again, both in the reports of the Canadian Survey and those made to the regents of the New York University,

* Before the Association of American Naturalists at Montreal in 1857. Prof. Hall thinks this is identical with his *Dictyonema* figured in vol. ii. of the Palæontology of New York, pl. 40 F. I have never seen the cells of that genus, and have some doubts of the correct reference. But the Professor speaks positively, and I have no means at present of deciding upon his assertion.

while describing the new and abundant material which has been so diligently collected together. His opinion will have great weight, but the evidence against it lies both in the mode of occurrence of these bodies, and even more in the very complete series of forms which can be furnished by our cabinets. It is even probable that the majority of the specimens we see *are* somewhat imperfect. But it is certain that in any rock where these remains of a single species are abundant, we should find some in a more or less perfect condition. It is moreover certain that the *Graptolites*, occurring in great shoals in muddy deposits, probably of a deep sea, often unaccompanied by any other fossils, and tranquilly laid down upon the soft carbonaceous mud, would be less likely to be broken up than most fossils. We might suppose that specimens found in sand or conglomerate would be mere fragments. But such as are invariably imbedded in soft shale should be as little likely to be disturbed or broken as any other kinds of organic remains.

M. Barrande has perhaps given the most perfect specimens yet figured, and in these the simple ones start directly from a pointed base, this base being moreover curved, sometimes strongly so, while the long stems of the ordinary species are often a foot in length. The *Diplograpsus*, or double *Graptolites*, evidently could never have consisted of two single *Graptolites*, the line of junction being quite soldered up; and to show that this is a character of structure, and not mere cohesion, we have only to refer to such forms as *D. ramosus*, in which the two rows of cells, when parted naturally as branches, have diverged at a considerable angle, the separation of the stipes being an exception, not a rule.

Didymograpsus is the next step in the series, a real bifurcation from the base; and the radix, minute in some species, is in others lengthened out into a long acute point, and the branches reflexed. *Dichograpsus*, proposed by myself in a short note to the Geologist, vol. 4, p. 74, for the very compound forms discovered by the Canadian Survey, carries the system of bifurcation further still. *Dendrograpsus* has the branches numerous, unsymmetrical, and crowded, while *Dictyonema* completes the series, by showing the numerous rod-like stems, each with their cells in double row, connected by numerous transverse bars into a network like that of *Fenestella*, to which indeed, I believe, it forms the passage group. Such a complete series of forms, from the simple rod with a few cells on one side, to double, forked, branched, cæspitose, and net-like forms, should find favour in the naturalist's eyes, as an unique group. It is perfectly certain we have the entire forms in each case, and I think, on further consideration, the eminent palæontologist of the United States will agree with us.

Graptolites sagittarius, Linn.

Pl. 11*a*, fig. 2.

Hisinger, Leth. Suec., t. 35, fig. 6; *G. virgulatus*, Schärenberg über Grapt., t. 1, figs. 8–11, t. 2, figs. 2–7; *G. Barrandei*, id., figs. 5–7; *Monograpsus sagittarius*, Geinitz, Graptol. t. 9, fig. 3; *G. incisus*, Harkness, Quart. Geol. Journ., vol. 7, pl. 1, fig. 8. p. 62.

The species is distinguished easily by the very prominent straight cells, truncated obliquely, without any reflection or contraction of the cell-mouth, and with a small spine (in some states) directly in the line of the cell from the lower angle of the mouth.

G. Barrandei of Schärenberg, seems to me to be exactly the same thing; and the species he figures as *G. virgulatus* is, I think, an ordinary variety with less distinct cells. It is difficult to fix the limits of *Graptolite* species.

Locality.—LOWER LLANDEILO. Llanfaelrhys, South Caernarvonshire.

Diplograpsus bicornis, Hall.

(Pl. 11*a*, fig. 1, *b. c.*)

Hall, Pal. New York, vol. i., pl. 73, fig. 2.

I see no tangible character to distinguish this (when the forked base is absent) from *D. teretiusculus* of Hisinger. It is, however, of a different aspect, for the cells, which are square, not pointed, are only half the distance apart, which they have in *D. teretiusculus*, and the whole frond is smaller. I

have never seen any above an inch in length (Hall figures it nearly double this length), while *D. teretiusculus* has often rods three or four inches long.

Localities.—UPPER LLANDEILO, Clarbeston, Haverfordwest; LOWER LLANDEILO, slopes above Tyddyn dicwm, near Penmorfa; Ty-obry. We have only the lateral view.

Diplograpsus teretiusculus, Hisinger.

Pl. 11*a*, fig. 3.

Hisinger, Leth. Suec., t. 38, fig. 4; Schärenberg über Graptoliten, t. 2, figs. 17–32.

This fine and very common *Graptolite* is a characteristic Llandeilo species, never falling, as I believe, below or rising above that formation. I have given the synonyms and reference to figures above, as I believe these truly represent the fossil. I might have quoted others less characteristic, and believe *D. rectangularis*, M'Coy, to be the same species.

Locality.—LOWER LLANDEILO; Ty-obry. Llandeilo Flags; Mona Mine, Anglesea; Llanerchymedd, &c.

Diplograpsus barbatulus, n. sp.

Pl. 11*a*, fig. 1.

D. foliaceus, angustus, cellulis obliquis rectis prominulis, quam latitudine axis longioribus, oribus transversis, sese spatium cellulæ remotis.

Though unwilling to name a single new species, I cannot find that this agrees sufficiently with any described ones. Professor Hall has figured so many forms under the name of *Graptolites pristis*, that it is impossible to say ours may not be identical with that figured in his plate 72, fig. 1*e* or 1*g*; but if the form we are in the habit of ascribing to the *G. pristis* of Hisinger be the true original species, this Lower Llandeilo fossil must receive a separate name, as the frond is much narrower, and the cells less crowded and less prominent. Hisinger's figure is more like our specimen, but has the cells too prominent and too little oblique to answer to it; on the whole it is safer to give a new name.

I believe the true *D. pristis* is the Caradoc species known under that name in Ireland, Shropshire, and South of Scotland. The Llandeilo flag species is, I think, nearer to *D. secalinus*, Hall; and this Lower Llandeilo form appears to me distinct from both.

Locality.—LOWER LLANDEILO. Ty-obry, Garth, opposite Portmadoc. (Mus. Pract. Geol.)

Diplograpsus ramosus, Hall.

Pl. 11 A, fig. 1, 1 *a*.

Hall, Pal. N. York, vol. i., Pl. 73, fig 3.

I have nothing to add to Professor Hall's description, but it is satisfactory to find this and other well-known Llandeilo flag graptolites extending their range into a lower formation. The Lower Llandeilo has all the shells, and nearly all its trilobites distinct, but the graptolites in the main are the same as those of the Upper Llandeilo, not entirely so.

Locality.—LOWER LLANDEILO. Ty-obry, near Garth, Portmadoc.

Diplograpsus mucronatus, Hall.

Pl. 12, fig. 1; Pl. 11*a*, fig. 6.

Hall, Pal. New York, vol. i., pl. 73, fig. 1.

Though but a small specimen, we must at present identify this with the species figured by Professor Hall. The peculiar shape of the cells, projecting outwards almost as much as their length, and their upper and lower edges so equal and alike, that it is difficult to tell the anterior from the posterior margin, easily characterize the species, and the long spine to the mouth completes the bizarre appearance of the species.

Locality.—LOWER LLANDEILO. Above Tyddyn Dicwm (pl. 11). Ty-obry, Garth, Portmadoc (pl. 11).

Didymograpsus geminus, Hisinger.

Pl. 11 B, fig. 8.

Hisinger, Lethæa Suecica, pl. 38, fig. 3 (not of Siluria, 2nd ed., p. 50, Foss. 8).

The true species, with branches running parallel or sub-parallel, is found in the dark grey micaceous slates of LOWER LLANDEILO, and with it, strangely enough, the following common species, which always seems to accompany it, both in Sweden and Britain.

Locality.—LOWER LLANDEILO. Cefn Gwynlle; Shelve, Shropshire.

(The Swedish form is from the Lower Graptolite schists of Aher.)

Didymograpsus hirundo, Salter.

D. geminus, Siluria, 3rd ed., Foss. 8 fig. 8 (not of Hisinger).

D. triuncialis et ultra, bipennis, ramis binis, usque ad angulum 180° *reflexis rectis. Rami ad bases angusti, dein latiores, cellulis approximatis, apicibus recurvis, serratis.*

Although this fossil differs in some respects from a common Swedish species, I do not hesitate to identify it at present, only premising that, if better specimens should turn up, the English form must retain the name; while the cognate appellation of the variety (*D. Cypselus**) may serve as a specific designation of the Swedish form. It is not unfrequently labelled *D. geminus* in collections.

The British fossil, commencing with a minute radicle, opens at once to an angle of 180°; instead of curving downwards for a very short distance, and then running straight outwards. But though this is the case with most of the Swedish specimens, a few have the character of the English form. The species appears to have grown to a great length, both in the Swedish and the British varieties. *D. geminus* is a totally different fossil.

The Swedish fossils come from the Lower Graptolite schists (Lower Oslo group, Kjerulf) of Aher, which I believe will have to be identified with our Lower Llandeilo.

Locality.—LOWER LLANDEILO. W. of the Stiper Stones.

Dendrograpsus furcatula, n. sp.

Pl. 11 A, fig. 5.

Not above an inch high, slender, repeatedly dichotomous at a small angle, and beset with numerous conical cells with simple mouths (and no spines) on a slender rhachis.

A small bushy species, of which the above is nearly all that can be said. As to structure, it is little more than a film on the surface of the iron-stained slate; but the simple shape of the cells can be made out, and they are very like those of ordinary *Graptolithus*, such as *G. Nilssoni* or *G. tenuis*. They are still more like the figures of branched *Graptolites* given by Hall. I think *Thamnograptus* of Hall can hardly be distinguished from *Dendrograptus*.

See report of progress for 1857 of Geol. Surv. of Canada. 1858.

Locality.—LOWER LLANDEILO. Ty-obry, Penrhyn.

Dictyonema.

Hall, Pal. New York, vol. 2, p. 174.

General character a rooted cup-shaped frond, of long, parallel, dichotomous branches connected by very irregularly placed processes (dissepiments). The branches of corneous texture (without a fibrous layer), with a double row of cells (which have projecting angular mouths) on the inner sides of the frond.

Dictyonema sociale (Salter).

Pl. 4, fig. 1.

Ref. Siluria, 2nd ed., Appendix, p. 541, 562; *Graptopora*, p. 47, Foss. 7, fig. 3.

D. triunciale, frondibus tubulosis congregatis, 3–4 ex eâdem radice tenui; ramulis parallelis approximatis; dissepimentis crebris.

The English species may not prove identical with the larger Scandinavian form (*Gorgonia flabelliformis*, Eichw.), and I have, therefore, given a separate

* The Latin name for the swift (*Hirundo apus*, Linn.)

specific character. But the two appear to me, except in size and in the regularity of the meshes, to differ in no important particular. M. Kjerulf, in a collection lately sent from Norway, included specimens of the Scandinavian form as *Fenestella socialis*, under which name the English species had been for some time in our cabinet. It was not until 1857 that I discovered the generic character in the projecting denticles of the inner surface of the ramuli: which character had also escaped Professor Hall, in characterizing the genus from American Upper Silurian specimens (Pal. New York, vol. ii., 1852, pl. 40 F, fig. 1). A description by myself of the genus *Graptopora* was read before the American Association of Science, 1857.

The fronds are frequently 3 inches long and 1½ broad at the top, cup-shaped, and pretty regularly conical. They are very generally grouped in threes or fours at the base, and must have grown obliquely, if not horizontally, as they now appear upon the slabs. The attachment (fig. 1*a*) is a short radicle, which soon branches into three or four dichotomising stems, and these again branch three or four times in the lower and middle part of the frond, till the full number of 30–35 parallel stems (or interstices, as they used to be called) are obtained, which end rather abruptly and regularly at the upper margin.

The branches themselves are minutely flexuous throughout, and throw off on either side thin processes (or dissepiments), very irregular in direction and position, sometimes oblique upwards, sometimes downwards, and not unfrequently two close together or partially coalescing (fig. 1*c* at †). The cells are visible even on the back of the frond as a double row on the branches, projecting a little on each side of them; they are rather closely set, about the diameter of the branches apart.

The mouths of the cells only show on parts of the English specimens (fig. 1*c* at *), but are clearly seen in those from Scandinavia, along the whole length of those branches which are laterally compressed.

They are projecting angular processes, exactly like the teeth of *Graptolites*, the lower edge oblique, and produced upwards into a short spine, the upper edge nearly straight and horizontal, or a very little concave. They are not unlike the cell mouths of *Didymograpsus geminus*, a species of *Graptolite* which occurs with Eichwald's *Dictyonema* in the lowest alum slates of Scandinavia.

The irregularity of the dissepiments is a character not very rare in *Fenestella*. The projecting corneous cells will, I think, separate *Dictyomena* from the *Fenestellidæ*, and probably constitute it a connecting link between that family and the *Graptolithina*.

It has long been doubtful to what class and order *Graptolites* belong. M'Coy stands almost alone in referring them to the *Sertulariadæ*. Most naturalists have followed Dr. Beck in classing them with the *Alcyonarian polypes*, *Virgularia* or *Pennatula* being the forms with which they are compared. And the figures by Geinitz and Richter of some branched and composite forms, probably belonging to the *Graptolithina*, have tended to confirm such a conclusion.

Prof. Huxley has suggested the *Polyzoa* or *Bryozoa* as a group to which these bodies might belong. The symmetrically branched forms connected by a corneous expansion at the base, found by Sir W. E. Logan in the Caradoc rocks of Canada, seemed especially to favour this analogy with *Defrancia*, &c. But there was no link to connect the horny tubes and long projecting cells of the *Graptolites* with any of the forms of *Bryozoa* so abundant in the Palæozoic seas.

This link, or one of the links, has at length been supplied by the present genus. The *Fenestellidæ* are recognized as an extinct group of *Polyzoa* allied to *Retepora*, and differing from it chiefly by the presence of a vertical fibrous layer on the reverse side. But all the known species are calcareous, furnished with the fibrous layer above noted, on which are set short cells quite distinct from each other; so that to convert a *Fenestella* into a *Graptolite*, even supposing we have the least branched species of the former, and the most complete of the latter to compare, it would be necessary to get rid of nearly all the calcareous material, reduce the skeleton to a mere thread (the axis), and lengthen out the cells enormously, while they were made fully to communicate with each other at their bases. The connecting processes too (or dissepiments) of *Fenestella* must be removed, as nothing

of the kind has yet been observed in the *Graptolithina* other than the present genus.

In a letter from Count Keyserling to Sir R. I. Murchison, he says that the *Gorgonia flabelliformis* is abundant in the lower schists of Russia as well as Sweden, and that Angelin had proposed the name *Phyllograpsus* in MSS. for it (Siluria, 2nd ed., p. 369, note). It is evident, therefore, that the Swedish palæontologist has observed the affinity above noted. And I would willingly have adopted his unpublished name, were it not that Professor Hall feels convinced* of the identity of this primordial genus with his Upper Silurian *Dictyonema*: were there, however, any doubt of the identity of the two genera, the name *Graptopora* would be more in unison with those of other genera of the *Fenestellidæ*, and at the same time indicate what I believe to be a true relation with the *Graptolite* group.

Locality.—UPPERMOST LINGULA FLAGS.—In black slate at Bron Foel slate quarries, S.W. of Tremadoc,—abundant. In beds in the railway above Plas Oakley, Maentwrog,—rare. Brampton Bryan Park, Pedwardine, Shropshire; Keys End Hill, Malvern.

Brachiopoda.

Lingulella, n. g.

Nearly equivalve, broad oblong, the ventral valve pointed and with a distinct pedicle groove. Muscular scars strong, nearly as in *Obolus*, but the pair of anterior retractors (C.) are more linear, and the sliding muscles (B.) small, and not quite so external as in *Obolus*.

The form, as well as what we know of the interior, is more like *Lingula* than *Obolus*; but the arrangement of the muscles in the only valve of which we possess the interior (ventral?) is more like the figures of *Obolus*. The anterior retractors diverge widely and are linear, the central (protractors?) come nearly down to them. And the external (or sliding) muscles are too small and too near the centre for *Obolus*.

The descriptions of *Obolella*, Billings, Geol. Surv. Repts. Canada, 1861, 1862, a good deal recal this, but his later figures show a very different set of muscular scars.

L. Davisii, M'Coy.

Pl. 2, fig. 7-12; Pl. 4, fig. 14.

SYN.—*Lingula*, Davis, Quart. Geol. Journal, vol. ii., p. 71; The Tremadoc *Lingula*, Sedgwick, ib., vol. iii., pp. 140, 143, 147; *L. Davisii*, M'Coy, Synopsis Woodw. Mus., pl. 1 L, fig. 7 (also when distorted as *Tellinomya lingulæcomes*, id., pl. 1 K, fig. 18); Siluria, 2nd ed., 1859, Foss. 4, fig. 1, p. 45, &c.

L. fere uncialis, lata, depressa, subplana, nisi ad apicem acutum paullulum convexa. Superficies regulariter striata, striis concentricis.

This, the commonest of all "Lingula flag" fossils, has been already well described as to its exterior by Professor M'Coy, and figured in the work above quoted. The specimens were brought to Cambridge by Professor Sedgwick, when he first assigned their true place to the Lingula flags in 1846, as the *Ffestiniog* group.

The very wide, depressed, and somewhat pentagonal form (satchel-shaped, M'Coy), the obtusely pointed beak, the straight edges meeting there at an angle of about 100°, and the irregular fine ridges of growth, have all been described accurately by Professor M'Coy. The interior presents everywhere traces of the points of connection with the mantle, both on the margin and on the ovarian region (pl. 4). The muscular impressions very rarely show at all, but, as above described, we have them in one specimen. The hinge area (in the more pointed valve at least, for we cannot be sure of it in the other) is flat, rather broad and striated: the groove for the pedicle is linear and well pronounced. The surface is remarkably even and regular, the median area not raised at all, nor distinctly striated, nor in any way separated from the general surface. The lines of growth are remarkably sharp and distinct, and yet are not regular

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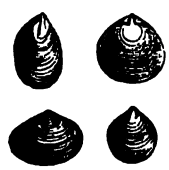
* In letters received from Professor Hall; also in his contribution to the reports of the Geol. Surv. of Canada, Rep. Progress, 1859, p. 142, where the genus is described, and the affinities of the *Graptolites* with other *Bryozoa* discussed, p. 144.

striæ. Nor can we in most cases detect any longitudinal lines. They sometimes occur over the anterior portion, pl. 1, fig. 11.

Localities.—Everywhere in the middle portion of the LINGULA FLAGS; rare in the lowest and highest portion, but of nearly full size again in the sandy beds of the UPPER TREMADOC slate. Specimens as nearly always more or less distorted; and in that state have been referred to *Tellinomya.*

Lingulella lepis, n. sp.

Fig. 11.



Lower Tremadoc, Borth woods, Portmadoc.

L. minor, vix semiuncialis, quam L. Davisii rotundior, ovata, apice acuto Impressiones musculares centrales profundi, paullo divergentes.

A smaller shell than *L. Davisii*, rarely occuring in the higher beds of the Lingula flags, but common throughout the Lower Tremadoc, and ranging also into its upper beds.

It is broad ovate, the beak short pointed, the form convex; the surface concentrically and sharply striate, with rather distant antiquated ridges of growth. Interiorly the pedicle has a short broad groove, and the central protractor muscles fill a narrow angular space, and are strongly bordered on each side. In *Obolella* they diverge widely, according to Mr. Billings' figures, and we have also a small species from the Upper Lingula flag (black shales) of Malvern?

Locality.—[LOWER and UPPER LINGULA FLAGS of the Portmadoc district.] LOWER TREMADOC slate, everywhere in the Tremadoc district, and also near Tai-hirion, Arenig. UPPER TREMADOC, Moel-y-gest, north side, and Garth, opposite Portmadoc.

Lingula, sp.

Lingula Davisii has been quoted from Marchlyn Mawr, Llanberis, Reports Brit. Assoc., Belfast, l.c., but the species is distinct, and not perfect enough to describe.

Locality.—LINGULA FLAGS. Marchllyn-mawr, N. of Llanberis.

Obolella, Billings, Canadian Reports, 1861–2.

Section *Monobolina*, muscular scars united closely along the central line.

Obolella plumbea, Salter.

Pl. 11 *b*, fig. 10.

Lingula plumbea, Salter. Siluria, 2nd ed., 1859, foss. 8, fig. 1.

O. magna (magn. O. cingulatæ, Bill.) latè trigona, ad frontem valde rotundata, ad apicem obtusa, lateribus superioribus rectis seu excavatis. Superficies glabra, lineis concentricis rugulosa, radiisque creberrimis ornata.*

A remarkably broad species, the breadth exceeding the length in the proportion of 4 to 3, with a pointed beak, slightly hollow upper margin, and broadly rounded below. The appearance is roughly pentagonal, but all the lower angles being so much rounded, it is not right to call it a pentagon in any sense. The surface is polished, but marked with many concentric rings of growth, and strongly radiated from the convex beak to the front margin. The muscular scars are remarkably strong and closely defined, and are less divided or bilobed than even in *O. pretiosa*, Billings, in which species this undivided character is most conspicuous.

It is probable we have not yet exhausted all the genera of the *Lingulidæ* from the very oldest rocks. And *O. plumbea* will likely enough in future form the type of a new genus, distinguished particularly by this union of the muscular scars. I have endeavoured to indicate this by the sectional name.

Locality.—LOWER LLANDEILO. W. of the Stiper Stones, abundant.

* I cannot adopt the term "posterior," as it must be so generally misunderstood.

Obolella, sp.

Pl. 12, fig. 7.

Our figure represents this small fossil as rather too pointed. I at one time referred it to *Lingula attenuata*, Sow., but it is clearly distinct, and probably belongs to the above genus.

Locality.—LOWER LLANDEILO. Llanfaelrhys, S. Caernarvonshire (with *Ogygia Selwynii* and *Graptolites sagittarius*).

Obolella, sp.

Pl. 12, fig. 8.

A more decided species of the genus than the last. It shows the central muscular impressions well, and has the rounded form usual in the genus. I do not pretend to give names to these fragmentary species.

Locality.—With the last.

Orthis, Dalm., 1827.

O. calligramma, Dalm.

Pl. 22.

DIAGNOSIS.—*O. semiovalis seu subquadrata, cardine longiori. Valvæ duæ lentè convexæ. Costæ simplices, interlineatæ aut numerosissimæ, virgulatæ; striis transversis, sæpe longitudinalibus, ornatæ. Processus cardinalis angustissimus linearis.*

Referring to the Memoirs of the Survey* for details connected with the several varieties of *Orthis calligramma* therein described but not figured, I will here only give the characters of the principal varieties from the Lower and Middle Silurian rocks of Wales. The species is a common one, and characteristic of the whole lower series. It has been so used repeatedly by Sir R. I. Murchison and other authors.

[The kindred British species also with large ribs, *O. Actoniæ* and *O. flabellulum*, are figured on the preceding plate by the same artist Mr. Bone, and are faithful portraits.]

From these two species it is readily distinguished by having both valves slightly convex; on the other hand the ventral valve is flat in *O. flabellulum*, the dorsal flat or concave in *O. Actoniæ*. But there is also a constant difference in the internal characters. The central tooth or cardinal process † is quite narrow-linear, and reaches from the beak as far back as the bases of the hinge teeth (or socket walls as Professor King terms them). These teeth diverge very regularly at an angle of about 80° or 90°, rarely less; and are narrow plates, a little thickened outwards, and leaving a subulate hollow between them and the hinge margin. In the cast, the interval between these bifid teeth filled up with matrix, presents a short broad pyramid, flanked by the subulate projections from the cavities under the hinge. The following are the variations of the surface.

In all the typical varieties, the ribs, instead of being angular as in *O. Actoniæ*, or simple undulations as in *O. flabellulum*, are raised squarish ridges, with an equal interval between them; both ribs and furrows being crossed by close transverse lines, and often striated by longitudinal ones.

In the beautiful figures by De Verneuil (Geol. Russia, vol. ii.), and in Irish specimens from Galway in our cabinet, this character is well shown. The length of the hinge line varies much even in those varieties which have the thick broad ribs, in the type *O. calligramma* it is much shorter than the width of the shell; in the var. *Orthambonites* De Verneuil figures some with a very broad hinge line greatly exceeding the general width of the shell, and he has also shown great variations in the number of ribs, from 14 or 16 to twice that number.

O. calligramma, var. *proava*, Salter.

Pl. 22, fig. 1.

Our Llandeilo type, fig. 1, agrees best with the squarer varieties of *O. calligramma* proper, and has the longitudinal striæ as well as the transverse

* Vol. ii., part I, p. 374.

† Davidson, Introduct. Brachiopoda, 1853, speaks of this as simple. It is always so in *Orthis* proper.

ones. Otherwise I should have been disposed to refer it to the variety *Orthambonites* of De Verneuil, whose description at least allows us to recognize two well marked races or sub-species, viz., those with and those without the longitudinal lines.

In form this Llandeilo variety comes nearest to Pander's *O. tetragona*, but that shell has at least 20 moderate-sized equal ribs. I think I might venture to distinguish it as a variety, recognizable by its convex shape and square form, with a hinge line equal to the shell in width, a convex dorsal valve rather deeply lobed, and with 14 strong ribs longitudinally striate, the middle ones remote, the outer ones interlined and smaller. The internal septum is short and strong,—the hinge teeth somewhat stouter than usual.

Locality.—UPPER LLANDEILO ROCKS, in grits among the black slates of Llanerchymedd, Anglesea.

Var. *Calliptycha*, M'Coy, (var. *plana*, Pander).

Pl. 22, fig. 2.

M'Coy describes his shell as a beautiful variety, differing chiefly from the ordinary form in the strength of the intermediate striæ. It has much the same form and proportions as the flatter valve of *O. plana*, Pander, and as M'Coy describes his variety (*Calliptycha*, Pal. Foss. Woodw. Mus. p. 215) as having only 18 instead of 24 ribs, I am obliged to refer to the foreign type. *O. ovata*, Pander, is a much more convex and elongate form, and I am not sure that De Verneuil has rightly interpreted it. The hinge line is shorter than the width of the shell; the dorsal valve flat, the area broad-triangular, the ribs square, and the interspaces strongly ribbed lengthwise. The ribs themselves show nothing but the transverse squamæ. And I suspect that this is the more common state, even in the extreme varieties next to be described.

Locality.—CARADOC Slates of Pembrokeshire.

Var. *virgata*, Sowerby.

Pl. 22, fig. 3.

O. virgata, Sil. System, pl. 20, fig. 15; Siluria, 2nd ed., pl. 5, fig. 9.

We have but one valve of this, and Sowerby only figured the same valve in the Silurian system. It agrees in shape pretty well with *O. plana*, or *O. lata*, Pander, having the hinge line somewhat shorter than the width of the shell. But it is a larger form, and has numerous, 36 or more, ribs, very regular and equal in size.

Locality.—CARADOC. Cwm-gwynen-uchaf, Montgomeryshire.

Var. *simplex*, M'Coy.

Pl. 22, fig. 4.

Orthis simplex, Sil. Syst. Ireland, pl. 3, fig. 18.

This, which is a convex shell, is wider than any of Pander's varieties, though most like his var. *rotundata*. It is a small shell too, and has about 32 (M'Coy says 24) equal ribs. But its wide form helps to conduct us to the following, which I cannot but regard as a mere variety.

O. simplex has well defined longitudinal and cross striæ, rather thicker hinge teeth than usual, and the space for the muscular impressions in the ventral valve is narrower than that in the majority of varieties.

Locality.—CARADOC, of Waterford, common.

Var. *plicata*, Sowerby.

Pl. 22, fig. 5.

Siluria, 2nd ed., pl. 5, fig. 7; Sil. System, pl. 21, fig. 6.

The hinge line is very wide, both valves are convex, the hinge area large and high, and the ribs are numerous, and, though regular and rounded, are frequently interlined. They are at least twice as numerous as in any of the previously described varieties. They show the cross striæ and frequently a longitudinal stria in the hollow between two ribs. Interiorly the teeth of the dorsal valve diverge very regularly, and these and the long thin central tooth or cardinal process are of the same proportions as in the other varieties. In a

good Bala specimen, Mus. Pract. Geol. 8/13, the hinge area is very broad, and the deltidial fissure very narrow. The cavity for the muscular impressions in the ventral valve is strongly ridged across the sides, and the vascular rays very strong quite up to the hinge plate, and also a good deal branched. The shell seems to have been rather thick.

Locality.—CARADOC. Bala.

Var. *Wallsalliensis?* pl. 22, figs. 6, 7.

O. Wallsalliensis, Davidson, Bull. Soc. Geol. France, 2nd series, vol. v., p. 339, pl. 4, fig. 7; Lond. Geol. Journ., pl. 27,

This might be described as an extreme form of var. *plicata*, for its shape agrees well. But there are the following differences, which bring it nearer to the var. *Wallsalliensis* of the Upper Silurian (ours is a Lower Llandovery variety).

The dorsal valve is more convex than in *O. plicata*, and the ribs, instead of being numerous and slightly interlined, divide into bundles of twos and threes from very near their origin, and again sometimes branching at half way down form fascicles of four or five ribs. There is an approach in the very numerous ribs to the *O. rustica*, Sow., which I regard also as a variety. That shell and *O. rigida* are however square and depressed, the latter furrowed down the middle. The shell here figured is in any case an extreme form, and yet the general aspect of the ribs, their rod-like form, cross striæ and regular intervals, above all the form and size of the interior teeth of the upper valve, decide me in referring all these varieties to one species.

Locality.—Lower Llandovery, Gas Works, Haverfordwest; CARADOC of Cefn Llwydlo, Brecknockshire.

It would be very difficult to say wherein any of Pander's varieties differ more than different individuals of ordinary species differ. And though there seems a wide interval between the type variety or the Llandeilo variety and the Llandovery and Wenlock forms, it is not difficult to show such a gradation from one to the other as to satisfy any impartial student that, to such extent as this the Darwinian idea must be a true one.

For the present it may be convenient to retain the names—

O. calligramma.
O. rustica (including *rigida*).
O. plicata (including *virgata*).
O. Wallsalliensis.

But I am convinced they all came from one stock, and that may have been the small and simple-ribbed form that we find in the Lower Llandeilo beds, pl. 11 B., fig. 12. A range from Lower Llandeilo to Wenlock Limestone is a considerable one. The species may nevertheless in its more typical forms be considered characteristic, as the author of Siluria insists repeatedly, of Lower Silurian rocks.

Orthis calligramma, Dalm. junior.

Pl. 11 B, figs. 11, 12. Pl. 12, fig. 5.

These small specimens appear to me to be in nowise different, except in size, from the ordinary forms of this species.

Locality.—LOWER LLANDEILO. Under the traps of Manod Bach, Ffestiniog, at a place called Cae-glyd, a locality rich in fossils and well worthy of search. Also in the arenaceous mudstones of Lords Hill, and other places west of the Stiper Stones, Shropshire.

Orthis alata? Sow.

Pl. 11 B, fig. 13.

Siluria, 2nd ed., Pl. 5, fig. 6.

Too wide for any varieties of *O. calligramma*, with which it occurs near Shelve. *O. alata*, Sow., has, however, besides the extremely wide form, so unusual for *Orthis*, a distinctly smaller set of ribs at the angles, which are not present in our specimen. I suppose it may be the young state of the species. The ribs

are, with this exception, like those of *O. alata*, but they are also like the varieties of *O. calligramma*, to which species it cannot belong.

Locality.—Lower Llandeilo, Lords Hill, Shelve.

Orthis, sp.

Pl. 11 B, fig. 14.

A small species, with few dichotomous and interlined ribs, which cannot be referred to any varieties of *O. calligramma*.

Locality.—Lower Llandeilo, Mytton Dingle; and Cefn Gwynlle, west of the Stiper Stones.

Orthis flabellulum, Sow.

Pl. 21, figs. 9–16.

Siluria, 2nd. ed., pl. 5, f. 12.

O. rotunda, transversa, cardine brevi. Valva dorsalis valde convexa, sinu nullo;—altera plana. Costæ simplices rotundatæ, per medium et ad marginem 2- vel 3-furcatæ, haud nisi striis concentricis lineatæ. Processus cardinalis ovatus.

I have figured the principal varieties of this fine shell, which is not only a characteristic but a very common one in all the Caradoc deposits, and so far as I know never ranges beyond them into higher or lower ones, nor occurs outside the British area.

It is useless to go into a minute description of so well-known a shell; suffice it, that it differs at once from *O. calligramma* and all its varieties, by having the ventral or larger valve flat, and the other convex without any median furrow. The interior characters are also widely different, the teeth thicker and larger at the end, the central or cardinal process broad, and shorter than the diverging teeth, much in the way they occur in *O. porcata*.

The muscular impressions (v. valve) are remarkably strong and square, very much after the pattern of those in *O. porcata*, which is, I fear, an extremely close ally, though much more irregular in its striæ.

The ribs of *O. flabellulum* are simple and rounded, as broad as the intervening furrows; and like them destitute of longitudinal striæ, but marked by close transverse lines of growth.

A few strong fringe-like varices of growth occur near the margin, giving the old shell an antiquated aspect, and at about half way down the shell the ribs fork in most of the varieties, and in many specimens fork again; when this is the case the ribs become angular instead of rounded.

In the extreme variety (var. *multifida*) from Snowdon, fig. 17, the number of ribs is greatly increased, but we are already prepared for such variations by the parallel case of *O. calligramma*. I have no doubt whatever that it belongs to the present species; and nearly the same variety occurs at Llanfyllin, Montgomeryshire.

Fig. 15 shows the general section of the shell, contrasting strongly with that of *O. Actoniæ*, pl. 21.

Locality.—North Wales and Shropshire, everywhere in Caradoc rocks.

Orthis porcata, M'Coy, var. *retrorsa*.

Pl. 19, fig. 4.

O. porcata, M'Coy, Sil. Foss. Ireland, pl. 3, fig. 14, 1846; Billings, Canadian Reports, 1862, p. 135. *O. occidentalis*, *O. sinuata*, *O. subquadrata*, *O. subjugata*, Hall, Pal. N. York, vol. i., pl. 32 a, b, c, pp. 126, &c. *O. inflata*, Salter, Quart. Geol. Journ., vol. i.; Mem. Geol. Surv., vol. ii., pt. 1; var. *retrorsa*, pl. 19, fig. 14. *O. inflata*, var. *retrorsa*, Salter, Mem. Geol. Surv., vol. ii., pt. 1, pl. 27, fig. 3. *O. retrorsa*, Billings, Canad. Rep., 1862, p. 136, fig. 112. *O. Carleyi*, Hall, 13th Reports of the Reg. Univ., p. 120. *O. grandis*, Portlock.

One of the commonest of Lower Silurian forms, and as such it has been described in its numerous varieties under many different names. In the Western States of America it is even more frequent than with us, and found in a more perfect state than even in Britain.

M'Coy's imperfect specimen was doubtless the first described and figured, and his name must be preserved. But the species exists in such abundance in America, and varies so widely, as to have received a great many names, a few

of which are given above. It is known in the Western States under the name *O. formosa.*

The species is more nearly allied to *O. flabellulum* than might at first be supposed, and like it has the dorsal valve highly convex, and the ventral valve flat or concave. Except in the irregular ribs, which are only to be found in some extreme varieties of *O. flabellulum*, there is but little difference between them. The specimens referred by Portlock to *Orthis grandis* are only fine varieties of this shell. *See* Mus. Pract. Geology.

Locality.—CARADOC rocks, all through Shropshire, S. Wales, and Ireland.

Orthis Actoniæ, Sow.

Pl. 21, figs. 1–8.

Siluria, 2nd ed., pl. 5, f. 11.

O. semiovalis, cardine longo. Valva dorsalis concava, sinu nullo; altera valde convexa fere involuta. Costæ paucæ, valde angulatæ, profundæ, minoribus interlineatæ, et ad marginem sæpe confertæ. Processus cardinalis ovatus.

Of this I thought it necessary to give complete figures, and shall point out the characters on which we may rely to separate it completely from *O. flabellulum*. There is no danger of confounding it with any other British species.

First, the relative convexity and concavity of the two valves is different in each. In *O. flabellulum* the receiving (ventral) valve is the flat or slightly concave one; in *O. Actoniæ* the reverse is the case. *O. flabellulum* has a hinge-line shorter than the whole width of the shell; in *O. Actoniæ* it is much wider, and produced into sharp ears. The former has rounded, the latter sharply angular ribs. And lastly, in *O. flabellulum* the ribs bifurcate; in *O. Actoniæ* they are simply interlined by other ribs (which towards the margin give rise to a cluster of small ribs).

There are no longitudinal and but few transverse striæ; sometimes these last are sharp and distinct. But a few distinct varices of growth are always present, and it is beyond the last of these that the sudden multiplication of the ribs takes place, which gives so curious an appearance to our fig. 3, and which has been well figured in Siluria.

Internally the dorsal valve (figs. 5, 6) shows thick slightly divergent teeth, and a narrow cardinal process (fig. 5), and the lamellæ which bound the muscles in the other valve are wide apart, much more so than is indicated in our fig. 3. The areæ are moderate and equal in either valve.

I do not know of any very well marked varieties of this common shell; nor do I know Pander's species well enough to identify with any of his figures at present.

Localities.—Everywhere in Wales and South Ireland in CARADOC rocks. In LOWER LLANDOVERY in South Wales, *e.g.*, Haverfordwest; Mandinam, in Caermarthenshire; Mathyrafal, in Montgomeryshire, &c.

Orthis lenticularis, Dalm.

Pl. 4, figs. 8–10.

Atrypa, Dalman, Kongl. Veteusk. Acad. Hand., 1827 (1828), p. 48; *Spirifer*, Von Buch, Berl. Akad, 1834, t. 1, figs. 13, 14; Jahrbuch, 1834, p. 616.

A well marked and very pretty species, and the earliest known in British rocks. It is hardly ever more than one-third of an inch wide, and most specimens are not half that size. The length is less than the breadth in proportion as seven to nine. Our figures represent the shell as distorted in various positions, but the above is about the average measurement. Both valves are somewhat convex, but the dorsal valve has a broad central depression of a triangular shape, bounded by two rather prominent ribs out of the 10 or 12 strong ones which radiate from the beak, and the sinus is occupied by two subcentral and very distinct ones. The lateral ribs are strongly interlined by others half way up, the intervening ribs soon becoming as strong as the primary ones, and these again by shorter and smaller ones in the intervals. All are crossed by strong but interrupted and rather wavy ridges of growth, so as to decussate the surface in rather a remarkable way.

The other valve is like in sculpture, but has a rather prominent beak, fig. 10*a*. The number of ribs varies greatly, but not in a way to make me believe we

have more than one species. Nor do I see in Scandinavian specimens* sufficient differences to warrant me in separating these, which occur in abundance in the alum slates in limestone layers.

The teeth diverge slightly in both valves; in the dorsal valve they are subparallel and short, or even curve a little inward, and are not thickened; while the cardinal process between them is a mere line or thin edge, which extends as far down as the length of the short lateral teeth, but is often very obscure, and sometimes seems to be altogether absent.

I have little doubt this is Dalman's species from Egeberg, though the specimens we have from thence have less prominent ribs, and a generally smoother appearance. There is no essential difference.

Locality.—UPPER LINGULA FLAG, Penmorfa Church, Tremadoc; near Criccieth, at Ogof-ddu Cliff.

Orthis alternata, Sow.

Pl. 19, figs. 11–13.

Siluria, 2nd ed., pl. 6, fig. 5. Sil. Syst., pl. 19, fig. 6. *O. retrorsistria*, M'Coy, Synops. Woodw. Mus., t. 1 H., figs. 12, 13.

The original figure by Sowerby in the Silurian System is from the typical variety so common in the "Jacobstones" of Shropshire. But the smaller and wider form figured here (from an unpublished plate in the possession of the Geol. Survey) is far more common in Wales, and we are able to show in it the large central tooth in the dorsal valve, which proves it, notwithstanding its resemblance to *Strophomena*, a true *Orthis*. The very large ventral muscles are peculiar and characteristic. There is altogether a curious imitative appearance about this shell. Fragments have been constantly mistaken for *Strophomena expansa* or *Leptæna sericea*. To both genera it has some relation.

Locality.—CARADOC slate rocks throughout Wales and Shropshire.

Orthis striatula, Conrad.

Pl. 13, figs. 10–14.

O. striatula, Conrad, sp. Emmons, Geol. Report, 1842, 394, illust. 105, fig. 3. *O. testudinaria*, Hall, Pal. N. York, vol. i., pl. 32, fig. 1. Salter, in Mem. Geol. Surv., vol. ii., pt. 1, pl. 27, figs. 6–8. *O. striatula*, id. in Siluria, 2nd ed., p. 544, foss. 10, fig. 16, 33 f. 3; Quart. Geol. Journ., vol. xv., pl. 13, figs. 14–16.

Our specimens from the Upper Llandeilo flags of Caermarthenshire are larger and finer than any figured in American works. The *O. striatula* is a very common shell in the Trenton limestone and associated strata of the New World, and Hall figures it of a medium size. But his description specially recognizes the distinctive character, the fine, close, elevated, thread-like concentric lines, which cover the surface and crenulate the ribs.

It has a remarkably flat upper valve, rather a long hinge line for the group, and but slightly diverging cardinal teeth, between which the narrow cardinal process is most prominent near the hinge margin: the ridge dividing the muscular impressions is very broad and low. A few antiquated lines of growth vary the surface in some larger specimens.

Locality.—LOWER LLANDEILO: [Lords Hill, Shelve ?], Sutherlandshire, as above, Quart. Geol. Journ. UPPER LLANDEILO: S. Wales. CARADOC? LOWER LLANDOVERY: north of Llandovery.

Rhynchonella ——, sp.

I need only mention here that a species, if not more than one, of this genus is rather abundant in some parts of the CARADOC rocks of North Wales.

The *Rhynchonellæ* in the Caradoc have been variously referred, and very erroneously, to several Upper Silurian forms. Portlock has no less than three Upper Silurian names (*T. crispata*, *T. plicatella*, *T. pulchra*) for differently compressed varieties of a common Tyrone species, which however is not perfect enough to name. It is distinct from the Upper Silurian species quoted, and appears to be identical with the one common along the rocky banks of Llyn Ogwen, in all the lower fossil bands near the foot of the lake.

* From Kinnekulle, W. Gothland. In the cabinet of John E. Lee, Esq., of Caerleon, Monmouthshire. His cabinet of fossils is a very choice one.

The species, though I refuse to be responsible for naming it till better specimens can be procured, is not unlike the *R. serrata*, a Llandovery species described from Galway by Professor M'Coy (Sil. Foss. Ireland, t. 3). The ribs are about as numerous as in the Irish species, in some specimens at least, but in none are there more than five ribs elevated; they stand up higher than in *R. serrata*, and the hinge plates within are thicker.

Lamellibranchiata.

Palæarca, Hall, 1857; *Cyrtodonta*, Billings, 1848.

[Family *Arcadæ*. Very inæquilateral, rhomboid ovate, ventricose, posterio ridge expanded. Umbones anterior. Anterior muscular impression deeply sunk, the posterior obscure. Hinge area undefined, hinge plate thick, arched, with a few (three) anterior cardinal teeth, placed beneath or in front of the umbo; and two or three remote oblique posterior teeth parallel to the hinge margin. Surface generally smooth, the siphonal ridge and posterior area only obscurely marked out. Pallial line simple. Ligament?]

Though inclined, as all naturalists must be, to admit the claims of priority wherever it is possible, it is not desirable at all to restore old and unmeaning names in preference to the one imposed by the first real describer. To insist on this would be to revive the old useless catalogues by collectors and dealers in place of a scientific nomenclature. This practice has been justly condemned by the late Dr. Woodward in his excellent treatise on shells, and in England at least the opinion which Forbes so strongly advocated is becoming general, that the rule of priority should be strictly observed only in regard to species.

The name of the present genus, one very common in the old rocks, is a case in point. It has simultaneously received two scientific appellations, each accompanied by a clear and sufficient description, when it is discovered by Professor Hall that his carefully described genus had been previously included, as to one of its typical forms, in the heterogenous group *Cypricardites*, proposed however by a real naturalist, Conrad. That genus is not only insufficiently described by Conrad (who included in it some forms of *Grammysia*), but the name is a misnomer, lending colour to the old idea that *Cypricardia* had numerous allies in the Palæozoic rocks. Its affinities are wrongly stated, and it is compared with *Pterinea* instead of *Arca* and *Nucula*. Professor Hall seems fully disposed to relinquish his own generic name, for which he claims a year's priority over Mr. Billings' *Cyrtodonta*, in favour of this older appellation, and in the Reports of the Regents he takes pains to urge the adoption of similar old and ill described generic groups among the trilobites, univalve shells, &c. Such a proceeding would throw us all into confusion. We believe Professor Hall will on reflection abandon this view. A species necessarily represents but a single form, and a host of difficult synonyms are avoided by the adoption of the first post-Linnean name. But genera are more or less abstractions, and always require great judgment in forming them. No premium therefore ought to be placed on hasty genus-making, but every discouragement shown to the practice. The general adoption of the first well-considered name, if accompanied by an intelligible description, is indeed most desirable, while the law of priority enforced without this safeguard would barbarize our nomenclature by depriving the names of our groups of all scientific meaning. Referring to those troublesome things called dates, it appears that Conrad's plate in 1841 was to supplement his descriptions during four years in the annual reports (*see* Reports Reg., No. 15, 1862). The imperfect description had then the advantage of a figure, and, had this figure been intelligible, Professor Hall, like all other working naturalists, would only have been too glad to avail himself of the name, as he has done in other cases. But the group included various forms, and the Professor, who separated *Modiolopsis** from it, does not appear to have recognized the typical form of *Cypricardites* till afterwards, when he had obtained good specimens of *Palæarca*. Such *contretemps* will continually happen, but we cannot permit an author of reputation to dismiss his own properly described types, in favour of antique and disused terms. As

* *Modiolopsis* is very imperfectly described by Hall. And to prevent future difficulty he should inform us what is his typical species. Prof. King has set all palæontologists a good example in this particular.

Palæarca appears to have been in some way in print in 1847, it is unfortunate that it escaped the notice of Mr. Billings, as it seems to have done that of all others. *Cyrtodonta* appeared in 1848 beautifully illustrated, while Hall's figures were probably already engraved for his third volume. No blame can be attached to either of the hard-working naturalists, and it is hoped their controversy may cease. [*See* Reports of the Regents of the Univ. New York, 12th, 13th, and 15th, 1859, 1860, 1862; Billings, in Reports Geol. Survey, Canada, for 1857, published in 1858; New species (*Vanuxemia*), 1857, id.; New Species, &c., June 1862; and Canadian Journal for 1861, p. 354.]

Palæarca Billingsiana, n. sp.
Woodcut 12, f. 4.

2 1

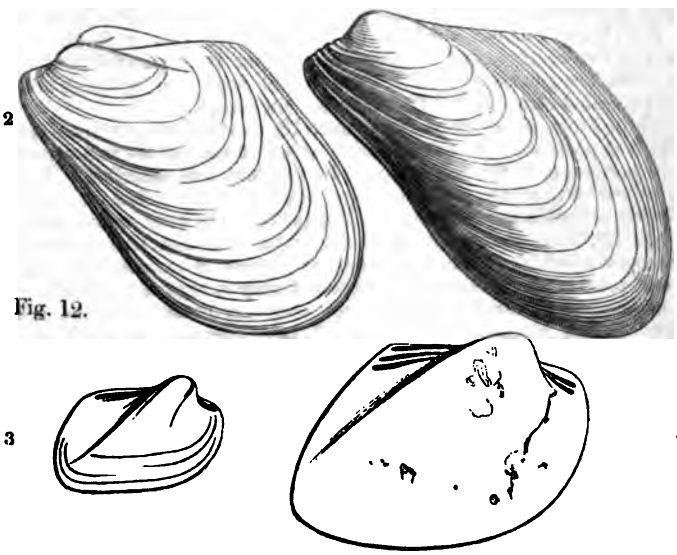


Fig. 12.

3 4

1. *Modiolopsis pyrus*, Salter.
2. *Palæarca modiolaris*, Salter.
3. *Palæarca quadrata*, n. s.
4. *P. Billingsiana*, n. s.

Obliquely rhomboid, ovate and rather compressed, 1½ inches long, and 1 inch high, depth of valves united 7-10ths of an inch. The beak is anterior, beyond the anterior fourth, the posterior side bluntly angulated, and much broader than the somewhat pointed anterior; the beak small, pointed, the siphonal ridge strongly marked from it to the posterior angle; making the cardinal slope steep and almost vertical behind the umbo. The hinge plate is narrow, with three radiating posterior teeth (in the left valve) and two anterior (cardinal) which lie parallel to the hinge margin, not across it. Anterior muscle not very deep. The lines of growth in this rather thick shell are not distinct, but we have only the inner cast. It is a compressed shell, otherwise it is much like in general character *P.* (*Cyrtodonta*) *Headi*, lately published by Billings from the Hudson river group (or Caradoc), of Toronto Canadian Reports, June 1862, p. 151). That more gibbous species is also more oblique than ours, and assumes just such a shape as ours would, if pressed obliquely from the hinge. But the American species are in better preservation than our own, and we must keep the forms distinct.

Locality.—CARADOC Slates, Nant Jorwerth, S. of Llangollen.

Palæarca obscura, n. sp.
Woodcut 13, f. 2.

Obliquely convex, and with the posterior side greatly enlarged, the beak almost lateral. The whole shell ventricose, thick near the hinge, the area of which is almost at right angles to the general direction of the shell. The beak placed somewhat nearer the anterior end of the short hinge plate, on which no

posterior teeth are visible; the anterior are short and thick, three strong ones, separated by deep broad pits, in the left valve, overhanging a very deep round muscular scar supported on the usual subcardinal ridge, in this case thick but not sharply defined.

Our figure represents the internal cast, and a view of the hinge plate. In the rounded form and very inæquilateral proportion, this shell most resembles *P.* (*Ambonychia*) *obtusa*, Hall, or the *P.* (*Vanuxemia*) *inconstans*, Billings, Canadian Reports, 1857, figs. 13, 15.

Locality.—CARADOC, Bala.

Palæarca? modiolaris, n. sp.

Woodcut 12, f. 2.

Oblique, posterior side much expanded, rounded and compressed; anterior small, rounded, somewhat divided from the body of the shell by a slight sinus; beak almost lateral, convex, scarcely tumid, and the siphonal ridge very slightly marked; hinge area very narrow, teeth—?; surface smooth, except occasional rugosities, the anterior side strongly striate. Length 2 inches, breadth across the posterior side 1¼ inch. Depth of valves united 1 inch.

The shell has much the aspect of a *Modiola* or *Modiolopsis*, but though no hinge teeth can be seen, I think we are safe in referring this straight-hinged shell to such oblique-ovate species of the genus as *P.* (*Cyrtodonta*) *canadensis*, Billings, and *C. Harrietta*, id. (Reports, 1862). I fear Billings' genus *Matheria* must be included in *Palæarca*.

Locality.—CARADOC, Bala.

P. (*Matheria?*) *quadrata*.

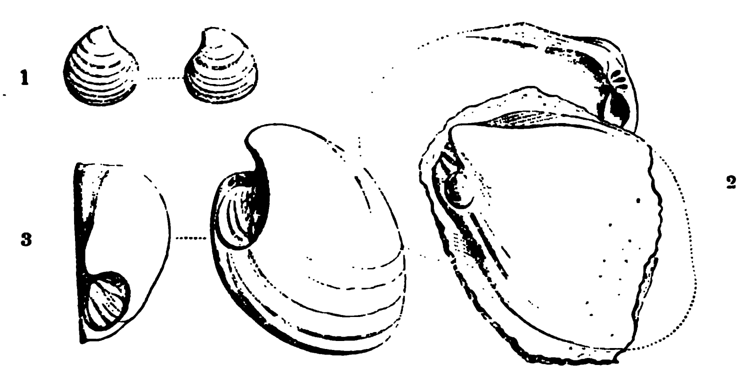
Woodcut 12, f. 3.

Oblong transverse, the posterior side not at all broader than the anterior, both ends somewhat truncate, beak prominent anterior, overhanging a distinct supine lunette; a strong siphonal ridge from the beak to the posterior angle, and another ridge marking off the anterior slope. These ridges are strong near the beak, but the anterior one becomes faint as it proceeds downwards. Shell thin, posterior teeth 2 in right valve. Anterior (two?) strong. Only one of the anterior teeth can be distinctly seen, it is parallel to the hinge margin. The shape of the shell is unusual for the genus, more like an *Edmondia* or *Orthonota*. It is, however, quite like *Matheria tener*, of Billings, and, also like that, a thin shell. If, as I believe, *Matheria* is only a section of *Palæarca*, the occurrence of two posterior teeth in the present species would help to connect the type species (*M. tener*), which has none. *Cyrtodonta subcarinata*, Billings, resembles it, but is too narrow a form, with the usual hinge of *Palæarca*, which has several teeth.

Locality.—CARADOC of Bettws-y-coed, N. Wales.

It is very probable that several of the so-called *Dolabra* (M'Coy) may belong to this genus.

Fig. 13.



1. *Ctenodonta varicosa.* 2. *Palæarca obscura.* 3. *P. bulla.*

Palæarca? bulla, n. sp.

Woodcut 13, f. 3.

P. ? rotunda, inflata, tenuis, rugis concentricis nonnullis antiquata. Umbones curvi, lunulam anticam profundam impendentes. Cardo dentibus tribus minutis anticis, postico unico. Musculi antici profundi.

I am convinced this might form the type of a new genus, were I ambitious of founding one. On the contrary, I rather earnestly deprecate the doing so till a number of species have been collected, or till at least a few have shown generic points in common. I refer it to *Palæarca* because that genus stands sufficiently near to indicate its relationship to the *Arcadæ*, and is a type containing several subgenera; and not to *Megalomus* which it resembles externally, seeing that is a massive shell and ours is a thin inflated one. *Megalomus* too has a sub-umbonal ridge remote from the muscle, no posterior tooth, and a thick laminated shell. It is probably, notwithstanding its pedal scars, one of its allies, and one of the *Arcadæ*.

The species has the deep anterior muscle, and the anterior teeth of *Palæarca*, and the subcardinal ridge bounding the muscular scar is strong, as in many of the Silurian *Arcadæ*. The posterior muscle is large and triangular, but ill-defined.

The anterior (cardinal) teeth 3 in the left valve, unequal of size, set on a rather thick hinge plate; a single strong remote tooth on the posterior side. All this bears on the generic character and its relation to *Arca* and *Nucula*. But the general form, inflated, round, with curved approximate beaks, reminds one of *Isocardia*, or at all events of *Cypricardia*, to which I believe it has no manner of affinity.

Localities.—CARADOC, Llanfyllin, N. Wales; S. of Llangollen, N. Wales; Horderley, Shropshire, abundant. (Mus. Pract. Geol.)

Palæarca socialis, n. sp.

Pl. 11 A., fig. 13.

P (? dubia), haud longitudinem unciæ attingens, transversè ovata, lævis, nisi lineis incrementi distinctis notata; latere antico brevi rotundato, postico producto nec angulato. Umbones elevatiores.

Three-quarters of an inch wide, and nearly 5 lines high, moderately convex, smooth, or with lines of growth only. The beak is near the rounded anterior end, but not very prominent; the posterior side produced but not angulated. The back straight, the ventral edge a little sinuated beneath the beak.

The whole form, in its uncompressed and undistorted form, is that of an *Arca*; but the extraordinary shapes it can take in the rock may be seen by the figures 11 *a. b.* They might easily be mistaken for as many species.

It is to be observed carefully that the earliest *Lamellibranchiata* known are everywhere referable to the *Modiola* or *Arca* groups, chiefly the latter. For this suggestive generalization we have been long indebted to Professor Phillips (Mem. Geol. Surv., vol. ii. pt. 1., pp. 263–275. (Lamellibranchiata lists, &c.)

Locality.—LOWER LLANDEILO BEDS.—Ty-obry, Penrhyn, opposite Tremadoc (abundant).

Palæarca amygdalus, n. sp.

Pl. 11 *b.*, fig. 17.

P. transversa, obliqua, mytiliformis, (curva ?) convexa fere gibba; latere postico elongato, antico nullo ferè. Umbo convexiusculus omnino terminalis, tumidus. Lunula minuta. Lineæ incrementi creberrimæ, validæ, majoribus squamatis remotis mixtæ.

A pretty species. Of the genus, for want of the interior, I am not quite sure. But it is like the figures given by Billings of the genus *Cyrtodonta*, which genus, as before said, appears to have been previously described by Hall as *Palæarca*. The obsolete anterior side is characteristic.

The shell is mussel-shaped, but for the rounded anterior end, and the curved general shape. It is obliquely gibbous, the diagonal convexity as well as the shell being bent rather than curved upwards. The dorsal edge is concave, the ventral highly convex, and the valves meet at a very obtuse angle—almost vertical in front, less so on the somewhat broader and posterior side.

The umbo is convex, but not much prominent, and is quite terminal, overhanging a small deep lunette on the very short obtuse anterior side.

The surface is marked by close sub-equal concentric lines, among which stronger ones here and there indicate the varices of growth. These become more numerous near the very obtuse front margin, where the valves meet one another all but vertically. The length of the valves is nearly 10 lines, the height 6 lines, the depth of the united valves 5 lines.

Locality.—LOWER LLANDEILO rock. Cefn Gwynlle Mine Works, N. of Linley Hall, Norbury.

Ctenodonta, Salter, 1851 (*see* Siluria, 2nd edit., p. 213).

The shells to which this name is applicable have been long known as species of *Nucula*, *Leda*, *Arca*, &c. in the old rocks. The discovery of very perfect specimens by Sir W. Logan in Canada first showed the true characters of the group; the external ligament being a striking distinction between it and ordinary *Nucula*. In other respects the palæozoic species are like the deep-water genera above quoted, some having a short posterior side like *Nucula*, others a long one as *Leda*.. Usually the form is transverse, but in a few the shape is very short and trigonal, and the following species is remarkably so. I have distinguished the genus from the *Isoarca* of Munster in the Canadian Decades, No. 1. Woodward includes it with that genus.*

Ctenodonta varicosa, Salter.

Woodcut 13, f. 1.

Nucula varicosa, Salter, Quart. Geol. Journ., vol. x., p. 75; *Ctenodonta*, Siluria, 2nd edit., p. 213; *Nucula levata*, M'Coy, Synopsis Woodw. Museum (not of Hall).

This species is very common in the Caradoc rocks (of North Wales particularly). It has been fully described by me in the Geol. Journ. above referred to. Its triangular shape, and extremely high and curved umbo, would almost distinguish it from any species except the *C. astartæformis* of Canada (Canad., Dec. I, Pl. 8, f. 7). Sharp, concentric, step-like lines of growth occur at pretty regular intervals over the surface, and give it a peculiar aspect. The *N. levata* of Hall has simple concentric striæ only.

Locality.—CARADOC sandstone and slate, everywhere; Bala; Conway falls; Montgomeryshire, &c.; Horderley.

Redonia anglica, Salter.

Pl. 11 B., fig. 15.

(*Cucullella?* Siluria, 2nd edit., p. 50., Foss. 8, fig. 2 (hinge badly figured).

Transverse ovate, half an inch wide, one-third of an inch long, very convex and regularly so, with the beak overhanging the broadest part of the shell at the anterior fourth. The beak is curved and sharp, and much overhangs the lunette. In front of it a strong, thick, rather curved plate reaches obliquely more than half way down the front side; the muscular impression being deeply imbedded in advance of it, short-triangular, and strongly circumscribed. The casts vary a little in shape, some being more convex. But the shape is always transverse, not rounded; and ovate, not triangular. (By some error, hinge teeth are inserted in the figure above quoted. There are no posterior teeth). It is not unlike *Redonia Deshayesiana*, Rouault, as figured by Sharpe in the 9th vol. of the Quart. Geol. Journ., but is too regularly oval. It is still more like the *Nucula Beirensis* of the same communication, yet it is a shorter, less rounded species, and even more convex.

Locality.—LOWER LLANDEILO. Lord's Hill, Shelve.

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* Manual of Shells, p. 260.

Ribieria * *complanata*, Salter.

Plate 11 B., fig. 16.

(*Redonia*, Siluria, l. c., fig. 3; *Ribieria*, in pp. 20? 549).

R. minor, valde compressa, subquadrata, margine dorsali et ventrali parallelis lentè curvis. Impressio muscularis posticus obscurus. Lamina antica brevis, recta, ad basin crassiuscula.

Although there is some uncertainty as to the group to which this curious fossil belongs, it is clearly distinct as a species from one described by Sharpe. Its dorsal edge is nearly straight, the posterior side as wide (even in the cast) as the anterior, and the whole shell is very much thinner than the Spanish fossil. The oblique anterior plate (a deep notch in the cast) is straight, sharp-edged, and extends across rather more than one-third the breadth of the shell anteriorly. It is sharp-edged, except at the base, where a small abrupt thickening takes place (while in the Spanish species the plate is broad and thick). The posterior muscular impression is scarcely visible.

Locality.—LOWER LLANDEILO. Lord's Hill, Shelve.

Modiolopsis pyrus, n. sp.

Woodcut 12, f. 1.

M. magna, 2½ uncias longa, 1¼ lata, inflata; latere antico acuto distincto minuto striato, postico elongato rotundo. Umbones obtusi, haud eminentes; margo cardinalis abbreviatus.

A peculiar aspect is given to this fine species by the regular convexity or rather inflation of the whole shell from the small beak outwards, the convexity not forming a siphonal ridge, but including the whole of the large posterior side, and only faintly distinguished by a slight sinus in the margin from the short acute and strongly striate anterior lobe.

The *M. modiolaris* of M'Coy (Pal. Foss. 1. I., fig. 17) is not an uncommon fossil in the Bala beds. But a comparison with Canadian specimens of the true *M. modiolaris*, Conrad, shows that the latter (though very like our British shell when Hall's good figures are compared) differs materially from the English species in being much flatter, having the anterior lobe both larger and less distinct from the body of the shell; the posterior side is also considerably less expanded than in the Welsh fossil, which should be called *Mod. M'Coyii*. We may take occasion to note how very few of the Silurian *Lamellibranchiata* are identical on the two sides of the Atlantic. The *Brachiopods* are much more like.

Locality.—CARADOC: Bala, North Wales, not unfrequent.

Gasteropoda.

Holopea, Hall. Palæontology of New York, vol. i., p. 169.

A genus instituted to include those smooth species of so-called *Turbo*, which are common in Silurian rocks, but which clearly do not belong to the operculated genus to which they are referred. The forms are very like *Turbo* in shape, but have no umbilicus; the pillar lip is closely reflected, and generally somewhat excavated. The typical forms are American. No very broad line can be drawn between this and the next described genus, *Cyclonema*, which, however, consists of more ornamented forms with concentric ribs or striæ. The whole group, *Holopea*, *Cyclonema*, *Trochonema*, &c., as described in Decade 1 of the Canadian Survey, belong rather to the *Litorinidæ* than the *Turbinidæ*, see Woodward's Manual.

The names of the following species were left in MSS. by the late Professsor Edw. Forbes, who regarded them as allied to the floating genus *Litiopa*, and proposed to name them *Litiopsis*. Hall's genus has the precedence.

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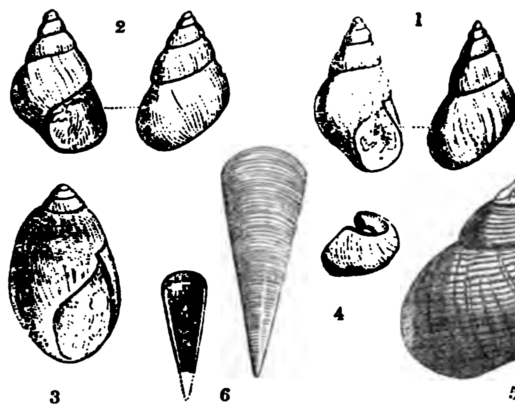
* A genus proposed by D. Sharpe, Esq., for a single species from the Lower Silurian rocks of Busaco, Spain. The genus has since been found in Bohemia, France, and Devonshire.

† The *Anatinidæ*, to which this shell is referred by Woodward, is no doubt the most likely affinity, if indeed it be a bivalve shell at all. I think it is a Crustacean allied to *Nebalia* among the Phyllopods. *See* Quart. Geol. Journ., 1863, vol. 19, p. 90. The shell is univalve in the Spanish species.

Fig. 14.



1. *Holopea exserta*, Forbes.
2. *Holopea conica*, id.
3. *Holopea lymnæoides*, id.
4. *Holopea carinata*, Forbes.
5. *Cyclonema crebristria*, M'Coy.
6. *Theca reversa*, Salter.

Holopea exserta, Forbes, MSS.

Woodcut 14, fig. 1.

H. uncialis, sublævis, spirâ acutâ producta ∠ 30°; anfractubus 5, lente convexis, rotundis, haud angulatis, ultimo spirâ paullo longiore, suturâ simplici nec appressâ.

This species is the most common in the Rhiwlas limestone. It has rounded whorls, not very convex, and the basal one is moderately and regularly ventricose, without any contraction at the suture. It is rather longer (but not much so) than the whole spire taken together. The shell has the look of a *Bithynia*, or a short *Bulimus*.

Locality.—CARADOC or BALA limestone, Rhiwlas, near Bala, Merionethshire.

Holopea conica, Forbes, MSS.

Woodcut 14, f. 2.

H. uncialis, anfractubus 5, convexis, subangulatis striatis; spirâ abbreviatâ, quam anfractu basali multo breviore. Basis convexa, a latere subconvexo angulo obtuso (in spirâ conspicuo) sejuncta. Striæ obliquæ, confertæ, vix regulares, nonnullis varicosis mixtæ.

Differs from the preceding by the less produced and rather blunt spire, formed of four gently convex whorls subangular below, the sutures strongly indented. The striæ of growth are oblique, sharp, tolerably close, but not regular; and are interrupted by rude ridges of growth near the mouth. The base is convex. There is no trace of an umbilicus. The shell has a general resemblance to the freshwater *Paludinæ*.

Locality.—Same as last, and a more abundant species.

Holopea lymnæoides, Forbes, MSS.

Woodcut 14, f. 3.

H. magna biuncialis, anfractu ultimo maximo elongato, ad basin effuso. Spira brevis. Sutura distincta nec appressa. Columella curva. Striæ rudes, obliquæ, prope orem ellipticum ut rugosæ.

A large species, putting one much in mind of the great *Lymneæ* or *Physæ* of the tertiary beds. Altogether these Bala univalves are very peculiar in character, and have little resemblance to Silurian shells.

Locality.—Same as last, rare.

Holopea ? carinata, Forbes, MSS.

Woodcut 14, f. 4.

H. semiuncialis, valde depressa, anfractubus 3–4, subangulatis ; ore subrotundo. Sutura distincta. Umbilicus apertus ?

Very nearly resembling, externally, the three last described species; but having a much shorter spire, and more depressed form. It has a thin shell, an oblique mouth aperture, and subangular whorls. But no portion shows the striæ of the surface, nor is the spire sufficiently complete to judge if it might be associated safely with the genus in which it is temporarily placed.

From many circumstances,—the finely levigated nature of the deposit, its great purity, and the quantity of *Encrinal* and *Cystidean* remains in the Bala limestone near Rhiwlas,—it is probable the bed was deposited in deep water. *Cephalopods* are common in it. And these thin univalves, which we have placed as members of the *Litorinidæ*, were, with much probability, considered by Forbes as floating shells. *Litiopa* belongs to the *Litorinidæ*, according to Woodward.

Locality.—Same as last.

Cyclonema, Hall.

Palæontology New York, vol. i.

This genus, proposed by Professor Hall, has been more fully described and its distinctive characters pointed out by myself in the work above referred to (Decades Canadian Survey, No. 1). It has much the aspect of *Litorina*, but was certainly a thinner shell than our modern species. Hall perceived the natural group formed by these ribbed and striated shells around *C. bilix* as a typical species, though no one has yet been able to give sufficient characters to distinguish it. I have ventured to separate the species with an open umbilicus (*Trochonema*) from those with a closely reflected and somewhat excavated lip, and I think the division a natural one.

Cyclonema crebristria, M'Coy.

Woodcut 14, f. 5.

Turbo crebristria, M'Coy, Synopsis Woodw. Mus., t. 1 K., fig. 36, 1 L., fig. 22. *Cyclonema crebristria*, Salter, in Appendix to Siluria, 2nd edit., p. 548.

Professor M'Coy has so well and thoroughly described this, under the ordinary name *Turbo*, that it is needless to repeat the description, and has compared its close striation and general appearance to that of *C.* (*Pleurotomaria*) *bilix*, Conrad and Hall. His figures, too, are both of them characteristic.

The shell was only moderately thick, the lines of growth very oblique, and rugose on the left whorl. The striæ, which are alternately larger and smaller on the upper part of the whorl, are of equal size and rather close together on the lower half; but the transition is a gradual one.

In the casts, which are the most usual state, the suture is deep and strong. The base of the shell is convex, a little angular below.

One of the most common of all Caradoc univalves in Wales. And I have found it, as has also Professor Sedgwick, in several localities of the May Hill sandstone or Upper Llandovery rocks. The *C.* (*Euomphalus*) *granulatus* of Portlock is closely allied, but cannot be identified with ours.

Localities.—CARADOC OR BALA. Everywhere in North Wales, Bala, Meifod, &c.; also UPPER LLANDOVERY rocks, Presteign, Radnorshire.

Ophileta or *Raphistoma*, sp.

Pl. 11 B, fig. 21.

A small species, not worth naming, but interesting as showing how nearly the fossils of the Calciferous sand-rock, and beds immediately overlying it, are represented in Britain by our Lower Llandeilo types. The specimen is presented by Mr. Lightbody to our cabinet.

To that gentleman, although his name is not often to be found in this memoir, geological science in England owes a real and lasting debt. Living at Ludlow, on the edge of the typical Silurian region, he has made himself thoroughly acquainted with the geology of Shropshire, especially down to the level of the Caradoc strata. His name is now widely known, and his credit

as an accurate and critical observer fully established. To his kindness and ready help the Geological Survey is largely indebted, and I take this public opportunity of acknowledging it.

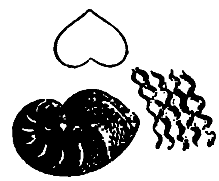
Locality.—LOWER LLANDEILO. White Grit Mine, Shelve.

Heteropoda.

Bellerophon nodosus, n. sp.

Woodcut 15.

Fig. 15.



Lines of growth magnified.

Salter, Quart. Geol. Journ., vol. x., p. 73. *B. ornatus*, M'Coy, Syn. Woodw. Foss., p. 310.

Spire exposed, of about three rapidly increasing whorls, which are half as thick again as broad, and of a subrhombic section; the umbilical faces rounded, and much shorter than the other flattened ones. Sides marked by thick raised ridges, which are not so broad as the intervening hollows; they are curved backwards towards the flattened dorsal keel, and nearly meet it, and extend over the rounded edge of the steep umbilicus. The lines of growth are beautifully regular, and they take a decided curve backwards along with the ridges. They are closely crenulate over the sides and back, and on the umbilical face reticulate with each other. Their reticulated appearance arises from the close approximation of the raised crenulate edges, which thus decussate each other, and become in some parts connected into a network. See magnified figure. The ridges or plaits vary in their distance from each other, but are very prominent.

This is the species described by Professor M'Coy, and we should have thought with him that it was *Cyrtolites ornatus* of Conrad, but that in Hall's figure and specimens we have from New York the lines of growth are direct across. In that species, too, the umbilicus has a sharper edge, and the plaits do not go beyond it. In ours it is obtuse, and they frequently run over it. Our shell is sometimes as large as the American species, and may possibly be identical, but there are the differences above stated.

Locality.—CARADOC SANDSTONE. Teirw River, south of Llangollen (Professor Sedgwick); Llwyn-yr-hwch, Beddgelert; near Llanfyllin; Hope Bowdler, Shropshire.

Bellerophon Arfonensis, n. sp.

Pl. 10, figs. 6–8.

B. latè involutus, uncialis et ultra, costato-striatus, striis remotis, arcuatis, asperis, etiam in sinu angusto vix marginato conspicuis; anfractu ultimo maximè dilatato, ore paullulum expanso (marginato?). Carina nulla.

An inch and a quarter in diameter, inflated; broad involute, the outer whorl greatly expanded, and deeply notched on the back. The lines of growth obscure, but accompanied by regular, sharp ridges at equal distances (in a specimen three-quarters of an inch diameter there are four in the space of a line). They show also on the notch or band, which is thus marked by prominent and rather remote arches throughout its whole length. Umbilicus open? Band not at all prominent, nor is there any depression of the whorl along it on either side. It is crossed by the arched striæ.

Fig. 6 may possibly belong to another species, as the lines, or rather ribs of growth, are scarcely visible, except on the younger portion. The lines or ridges of growth are parallel to the margin of the mouth, and are sharp and almost crested. In fig. 8 they are one-tenth of an inch apart, and yet this is a

young specimen. Fig. 6 shows the mouth with the umbilical edge slightly recurved, but of course the shape is materially altered by pressure.

Locality.—UPPER TREMADOC. Garth, Penrhyn; also Tu-hwnt-yr-bwlch, Portmadoc. Several specimens have been found by Messrs. Ash and Homfray.

Bellerophon multistriatus, n. sp.

Pl. 10, figs. 9, 10.

Broadly involute, whorls rapidly increasing, umbilicate, with close arched striæ of growth (most conspicuous away from the umbilical edge), much curved, equidistant, and with numerous plaits or folds crossing them, which do not seem to indent the outer margin of the growth ridges, but only the spaces between, giving a fimbriated appearance.

It is easily enough distinguished from its companion species, *B. arfonensis*, figs. 7, 8, by the close and fimbriated ridges of growth. And it characterizes rather an older set of beds, being chiefly found at the point of junction between the *Upper* and *Lower Tremadoc*.

Locality.—UPPER TREMADOC. North face of Moel-y-gest, Portmadoc, Garth, &c. Also at Llanerch, in the passage beds to LOWER TREMADOC. Cabinets of Messrs. Ash and Homfray, also of Dr. Ogle.

Bellerophon hippopus, n. sp.

Plate 11 B, fig. 2.

B. latissimus, uncialis, striatus, vix costatus, anfractu ultimo maxime dilatato, striis inæqualibus conspicuis. Carina lata prominens. Apertura paullulum contracta. Umbilicus profundus.

Broad-involute, the outer whorl very wide, and rather depressed on the back with something of a furrow on each side of the broad band, which is rather prominent and well defined in all ages. Striæ arched backward, every third or fourth one stronger than the rest, but not producing prominent ridges as in *B. arfonensis;* nor do they form conspicuous ridges on the band as in that species. Umbilicus open, broad, deep.

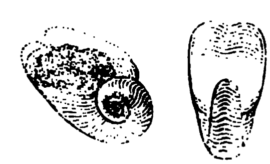
Differs from *B. arfonensis* by the prominent band, less regular arched striæ, and unexpanded mouth, as well as by the extremely wide shape; the transverse being apparently much greater than the longitudinal diameter.

Locality.—LOWER LLANDEILO FLAG. Ritton Castle, west of the Stiper Stones.

Bellerophon perturbatus, Sow.

Euomphalus, Silurian System, Pl. 22, fig. 15. *Euomph. furcatus*, M'Coy, Sil. foss., Ireland, p. 13. *Bellerophon perturbatus*, Siluria, 2nd ed., p. 218, foss. 39, fig. 6.

Fig. 16.



Restored from good specimens. Upper Llandeilo, S. Wales.

We give a far better figure, from complete specimens, than could be given by Sowerby in the original work.

It has long been known that it was a *Bellerophon*, of the group *Euphemus*, M'Coy, and that *Euomphalus furcatus* of that last-named author was a synonym. It is not so generally known that it is one of the very best and most characteristic species for the *Llandeilo flags*, being common in British localities, in N. and S. Wales, and very rarely met with (in Ireland only) in rocks supposed to be of the Caradoc era.

Locality.—UPPER LLANDEILO. Bath house, Bangor. Abundant in Upper Llandeilo rocks in N. and S. Wales; and in CARADOC? S.E. Ireland.

Pteropoda.

Theca.

Fam. *Hyaleidæ?* — Shell straight, sheath-shaped, triangular, compressed, without lateral appendages or spines of any kind. Mouth closed by a semicircular operculum, with the nucleus on the straight (dorsal) edge.

There are two groups of the shelled *Pteropods* known, one with straight or slightly curved shells and no operculum; the other with spirally rolled shells, furnished with an operculum lobe, and, in *Spirialis* at least, with a shelly opercular plate.

To the former of these, from its analogous form, the palæozoic *Theca* and its allies have been always supposed to belong. No evidence has yet been published of shelly plates connected with these common shells, or with *Conularia* or its allies.

The fossil here figured, however, has constantly associated with it, and often in juxtaposition, a shelly plate which would just fit the aperture, and there can be no reasonable doubt that they belong to the shell, since they are found in plenty with it in the Shelve and Tremadoc districts. The *Theca* associated with it in the one case is a distinct species from that in the other, and this being so, it is probable that other species of the genus may possess a similar covering plate.*

It is not unworthy of remark, that while the bulk of the recent *Pteropods* are without opercula, and *Theca* appears to have one, the case is similar with the recent forms of *nucleobranchs* (*Heteropoda*), scarcely any of which have opercula, while the largest and thickest operculum known in the Silurian rocks belongs to an abnormal fossil *Heteropod*,—*Maclurea.*

T. (*Cleidotheca*) *operculata*, n. sp.

Pl. 10, fig. 22–24.

Short-conical, apical angle about 25°, with a compressed section; the dorsal surface nearly flat, projecting a little beyond the ventral, which is convex. No regular longitudinal ridges or furrows occur upon the shell, and the surface is remarkably even, except for the strong, sharp, curved lines of growth that cross it.

Operculum a semicircular plate, abruptly bent parallel to and near the straight margin. The larger area is a very wide and flat segment of a circle (almost a semicircle), divided from the narrow marginal area by deep wide furrows radiating from the nucleus, and partially bisected by a shallow furrow commencing from the same point. One or two radiating lines occur also near the furrows.

The bent portion of the plate is a narrow sub-triangular area, and is bisected, like the other and larger area, by a short central furrow.

The short proportions readily distinguish this species from the following, which occurs in equal plenty with it.

Locality.—Lower Tremadoc. Abundant in all the localities near Portmadoc, associated with large trilobites of two or three genera.

Theca bijugosa, n. sp.

Pl. 10, figs. 19, 20.

Elongate (apical angle about 10° or 12°), the dorsal side convex, and ridged by three distinct keels—the central one of which is strongest—from the apex to near the mouth; the others faint at their origin, but becoming stronger near the aperture. On the flatter side a corresponding furrow appears to exist, but we have very little evidence with regard to this surface. Lines of growth inconspicuous, but greatly arched, following the very prominent margin of the mouth on the dorsal view. All our specimens are views of the dorsal aspect, except one from the Upper Tremadoc slate, and that appears to have a corresponding deep furrow; but it may only be a deep impression made from the opposite surface.

* Since this was written I learn from M. de Barrande that he has long had several species of *Theca* in his Bohemian collection with opercula, and in some cases actually attached to the shell. It may be a generic character, but I retain the sub-genus for the present.

Locality.—LOWER TREMADOC, with the last. UPPER TREMADOC, same district; one upper figure not numbered on the plate.

Theca arata, n. sp.

Pl. 10, figs. 15 and 21, and possibly figs. 17, 18.

Conical, rather short, apical angle about 15°, dorsal surface flattened, but with a raised central keel, on each side of which are one or two furrows. The lines of growth on this surface are very strongly arched; the mouth projecting a good deal. They are also prominent as raised threads, and almost rugose, much more so than in the last species. The ventral plate appears to be slightly concave, and the striæ are a good deal arched forward, and equally rugose with those on the opposite surface.

Locality.—LOWER TREMADOC, near Penmorfa Church, Tremadoc.

A variety? with similar dorsal keel and furrows, but smooth, or with only faint lines of growth, occurs in the UPPER TREMADOC, Penyclogwyn and Tu-hwnt-yr-bwlch, both near Portmadoc.

Theca simplex, n. sp.

Pl. 11 B, figs. 22–26.

An inch and a quarter long, and one quarter broad, triangular in section; the dorsal surface nearly plane, a little convex, quite smooth, and with a gently arched mouth-margin. The ventral surface highly convex, with a few longitudinal lines, but no ridges, and crossed by direct lines of growth only. The mouth is frequently a little expanded. The operculum occurs in company.

There are not many characters to distinguish this species; but it is clearly not the same as the Upper Silurian *T. Forbesii*, being much more highly convex on the ventral side, and flatter on the opposite side, besides being of a much longer shape.

Locality.—LOWER LLANDEILO. White Grit mine, Shelve, abundant.

Theca vaginula, n. sp.

Pl. 10, fig. 14. It should have been in pl. 11 B.

Short-triangular, pointed, almost acuminate, ventral? surface very convex, bluntly angular along the central line, and with a narrow marginal rim. Dorsal surface flat? Edge of mouth?

It was premature to name this small species from a single specimen. But I find that there are several specimens of apparently the same form in the Lower Llandeilo rocks of Shelve, and they do not agree quite with any of the Tremadoc species here described.

Locality.—LOWER LLANDEILO. Tai hirion, near Arenig fach, on the Bala road.

Theca obtusa, n. sp.

Woodcut 17.

Fig. 17.

Shell very thin, straight, rounded in section, tapering backwards, and with a blunt rounded termination, and with two marginal thickened lines (surface obscurely marked by short longitudinal striæ). Nearly one inch long, and half an inch broad above. It would be very rash to constitute a new genus from a single crushed specimen. This is certainly not an *Orthoceras*, for which it might have been mistaken in newer rocks. It is very thin, has apparently

two thickened margins running to the angular lateral edges as in *Theca;* but its termination is rounded and blunt, instead of tapering to a fine point.

Believing, therefore, that it cannot be *Orthoceras,* I am tempted to make the most of its *Pteropod* character; and as none, except a *Theca,* has heretofore been found in Primordial rocks, it may be presumed to be a large species of that genus till better material shall occur.*

Locality.—LOWER LINGULA FLAGS, Maentwrog Waterfall. Presented by Mr. Ash to the Mus. Pract. Geol.

Subg. *Centrotheca.*

Shell straight, sheath-shaped, triangular, or compressed; mouth with long curved lateral appendages.

T. (Centroth.) cuspidata, n. sp.

Pl. 10, fig. 25.

Broad-conical, the apical angle about 30°; the length about eighth-tenths of an inch; the breadth, three-tenths. The (dorsal?) surface gently convex, a raised central area being more so than the rest, and this is marked with faint longitudinal ridges (three or four in one specimen, only a central ridge in another). The edge of the mouth is not greatly projecting in front, but it is thickened, and is produced on either side into a long curved spine. In one specimen this is four-tenths of an inch long.

Locality.—UPPER TREMADOC Flag. Tu-hwnt-yr-bwlch, Portmadoc. (Presented by Mr. D. Homfray.)

Theca reversa, Salter.

Woodcut 14, fig. 6.

T. triangularis, Hall, Pal. New York; *T. reversa,* Salter in Siluria, 2nd ed., p. 550; Foss. 10, fig. 21.

A common species, which ought not to be confounded with the Upper Silurian shell (*T. Forbesii*), though much resembling it in shape and size; it only differs from that species, so far as I know, by having the dorsal plate convex. In *T. Forbesii* this is quite flat, and the front strongly angular. In this the dorsal surface is convex, and the ventral less angular. With the greatly elongated *T. triangularis* there is but little affinity.

Not an inch long, one-third of an inch wide at top, and rather quickly tapering. Dorsal surface gently convex, its front margin much projecting. The ventral surface angular, but not sharply so. Lines of growth very indistinct.

A pair of faint elevations are seen running lengthwise down the back, and in one specimen (interior cast) an internal thickened ridge runs along each side a little way from the margin. This ridge is common to several species.

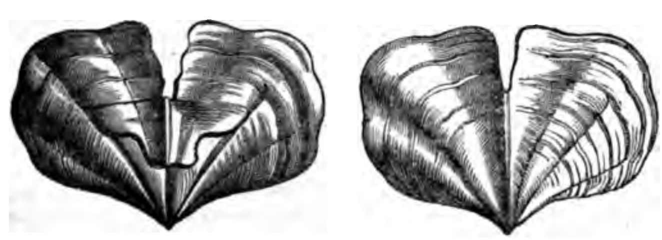
Localities.—CARADOC. North Wales; Horderley, Shropshire; S. Scotland; Bird's Hill, Llandeilo, South Wales.

Genus *Pterotheca.* Shell transversely oval, bilobed, with wavy sides and a strong median keel. Ventral plate short, narrow, and flat (*see* Siluria, 2nd ed., Foss. 39, fig. 4).

Pterotheca corrugata, Salter.

Brit. Assoc. Reports, 1852,—Trans. Sect., p. 61; Siluria, 2nd edit., p. 550.

Fig. 18.



* Better specimens have since been found by my indefatigable friend, Mr. Homfray; near Tafarn helig, S. of Maentwrog.

P. lata, undulata, margine repando. Carina dorsalis valde elevata. Apiculus minutus.

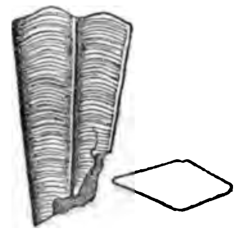
This fine fossil, originally described in the British Association Reports along with the typical species, has only as yet occurred in one locality. It is abundant there, and shows casts of both back and front, as well as the triangular plate which encloses the visceral cavity. The extent to which the sides or wings expand is remarkable, very much greater than in any other genus now living. Such marginal expansions in one form or another are, however, not uncommon among the *Pteropod* and *Heteropod* groups. Barrande now finds the genus in Bohemia, and Hall in North America.

Width, 1⅓ inch; length, nine-tenths of an inch. The form is widely transverse, deeply notched in front, and marked by five broad undulations which reach from the beak to the margin, causing a wavy outline. These undulations are crossed by other waves in the direction of the lines of growth, so that the whole shell is rugose. The dorsal plate is strongly curved, almost boat-shaped, and has a strong median elevated keel, reaching all the way to the minute beak, and probably (but it is broken off) to the upper front margin. The lines of growth meet this keel everywhere at a right angle, and are not deflected by it. The small ventral plate is perhaps quite flat, but in one much-squeezed specimen it has a central ridge corresponding to the dorsal keel; and this may be the real character. The plate is flat in the other species, one of which is Lower and the other Middle Silurian.

Locality.—CARADOC, Dolbenmaen, near Criccieth; several Nuculoid shells accompanied this (probably) deep-water form.

Conularia lævigata, n. sp.
Woodcut 19.

Fig. 19.



A compressed specimen, with a rhomboidal section; it tapers slowly at 15°, probably less, and is seven lines broad, and fully 1¾ inches long. The faces are flat or even a little convex, the two neighbouring ones which meet at one of the acute angles being rather broader than the other two. Surface nearly smooth; the lines of growth irregular in thickness, gently arched across each face, without being angularly bent in the middle. Furrows at the angles rather shallow.

The rhomboidal section may be the result of pressure, but it does not appear to be wholly due to it, and as the two smaller faces meet at one of the acute angles, and the two larger at the other, the shell is probably near its true form. On the smaller face the striæ seem to rise to a higher level towards the angle furrow than towards the lateral one, a character observable in some other compressed species.

The irregular and simply arched lines of growth distinguish this easily from *C. subtilis*, Salter. *C. elongata*, Portlock, has a strong median furrow on each face.

Locality.—CARADOC. Llwyn-yr-hwch, 3 miles south of Beddgelert, North Wales.

Conularia Homfrayi, n. sp.
Pl, 10, figs. 11–13.

C. tenuis, fere membranacea, magna, 4-5-uncialis, elongato-conica, quadrato-cylindrica, apice acuto; costis tenuibus longitudinalibus crebris, nullis transversis, ornata. Costæ in angulo quoque binæ, in faciebus 2-4 filiformes, interstitiis undulatis et rugatis. Lobi oris lanceolati-obtusi, membranacei, ecostati, haud connirentes.

Four inches and a half long, and three-quarters wide at the larger end, conical, with straight sides, sharp pointed apex, and double ridges, eight in number. No distinct transverse rugæ are present, but the surface is a little rugate or puckered between the ridges. These ridges occur at each angle between the faces, and there are two, three, or more along the middle of each face; the lobes of the mouth are broad-pointed and tongue-shaped in front and behind, shortest on the sides, and not bent inward or contracted as in kindred species.

The nearest ally of this fine shell, unexpectedly met with so low down in the Protozoic series, is an unpublished species in the Ludlow rocks of Shropshire. It is somewhat larger than this, broader in outline, and has the ridges along the middle of each face, but not along the furrows between the faces. It differs still more markedly in having the mouth contracted; and all the lobes bend inward towards one another, so as partially to close the mouth in the adult form. Very probably these two and other allied species will constitute a distinct genus, when we know enough of these old *Pteropods* to classify them more completely.

Locality.—UPPER TREMADOC. Garth Hill, abundant; Tu-hwnt-yr-bwlch. Collected by Messrs. Ash and D. Homfray, of Portmadoc. The figured specimens are from the cabinet of Mr. Homfray, and from the Woodwardian Museum, Cambridge. [Also M. P. G.]

Conularia margaritifera, n. sp.

Pl. 11 A., fig. 12.

C. modica, segmentis (uno solùm conservato) planis? striis transversis valde obliquis, ut S. curvis, tuberculis minutis longitudinalibus ornata. Sulcus subcentralis.

A small species, apparently with a thin shell. We have only a fragment of one segment, and that is covered by regular, rather imbricating striæ, which run very obliquely across in a sigmoid curve. Fine longitudinal striæ, scarcely to be called tubercles, are easily traceable on the ridges, but they do not cross the intervening hollows. The sulcus is subcentral, and very little interrupts the course of the ridges.

I know of no species that can be well compared with this; the sigmoid ridges easily distinguishing it from all the Silurian forms known; for comparison with other forms of the genus see Dr. Sandberger's paper in the Neues Jahrbuch for 1857. Pl. 1.

Our species is a true *Conularia*, not a *Coleoprion*, as may be seen by the central line.

Locality.—LOWER LLANDEILO. Ty-obry, near Garth, Tremadoc.

Conularia Corium, n. sp.

Pl. 11*a*., fig. 11.

C. fere pedalis, lævis (quasi coriacea), quadrato-cylindrica, angulis vix (nisi ad orem) prominulis; sulci angulorum facierumque æquales, angusti; striæ transversæ nullæ.

Nine or ten inches long, at least one and a quarter broad, and slowly tapering; sub-cylindrical in section below, sub-quadrate above, with sharp narrow continuous furrows at the angles, and somewhat interrupted ones in the middle of the faces. At about half the length the angles begin to grow a little prominent, and thence continue more and more prominent to the mouth. The furrows on the faces are in parts less continuous, lie nearly in the middle of the faces, and only near the mouth are elevated upon ridges. They are flanked by two fainter ones for some distance from the mouth. The shell is not contracted or lobed at the mouth, as in *C. Homfrayi*, nor is the substance, which seems to have been coriaceous throughout, thinner or more membranous at this part.

No transverse striæ or ribs of any kind are visible, and the whole shell has a smooth surface, and is so much bent as to give the idea of its having been of a flexible material, rather than a rigid shell.

I do not feel sure it is distinct from the great *C. pyramidata* of the May sandstone, Normandy. See fine specimens in the Mus. Geol. Society.

Locality.—LOWER LLANDEILO. Ty-obry, Penrhyn; near Tremadoc. Three specimens were found by our collector, Mr. R. Gibbs.

Cephalopoda.

Orthoceras encrinale. Salter.

Pl. 11 B., fig. 20.

Siluria, 2nd ed., p. 50, Foss. 8, fig. 10.

Some inches long, and less than half an inch broad. Cylindric, closely annulated by somewhat oblique prominent rings; which are rounded, not keeled, or imbricate, or marked by striæ of growth (at least in the inner cast), and as broad as the rounded interspaces.

This is an older portion; when the diameter is only one-third of an inch, the rings are sharper edged, not so broad as the interstices, and often wavy, and show some traces of intermediate wavy striæ. The shell may have been covered with such markings outside, and in that case would have a considerable affinity to the group of *O. annulatum*.

Locality.—LOWER LLANDEILO. Cefn Gwnylle Mine, Shelve, Shropshire. (Mus. Pract. Geology.)

Orthoceras Avelinii, Salter.

Pl. 11 B., fig. 18.

Siluria, 2nd ed., p. 50, Foss. 8, fig. 4.

A common species, seldom found of more than three-quarters of an inch broad, and which must have measured about six inches in length. Section round. Siphon excentric, placed one-third the whole diameter from the margin, small. Septa flattened, very little oblique, two in the length of a diameter where the shell is half an inch broad. Shell rather thin, strongly striated direct across, except a slight downward wave on the opposite side to the siphon; the striæ coarse, imbricating forwards, and sometimes interlined irregularly.

The tube is quite cylindrical and even for all its older portion. But the young shell is slightly annulated in the direction of the septa, and the projection is along the line of the septum, the shell being contracted between each.

This may possibly be only a variation in individuals, but the character is worth notice. The species is allied to *O. subundulatum* and the other thin-shelled striate species, so common in the Silurian rocks.

Locality.—LOWER LLANDEILO. Cefn Gwynlle Mine, Shelve. Collected by Mr. Gibbs. The species is named after our veteran geological surveyor, Mr. W. Talbot Aveline.

Orthoceras sericeum, n. sp.

Pl. 10, fig. 4, 5.

Probably 10 inches to a foot in length, but not above three-quarters of an inch broad, surface marked only by transverse (oblique?) lines of growth, which are not prominent, but rise into more conspicuous ridges at short intervals, particularly near the mouth.

The septa are remarkably numerous and close, in fig. *a* pressed laterally and therefore a little lengthened. There are 19 in the space of an inch. In fig. *b*, which is somewhat shortened by pressure, there are 20 in an inch As they are oblique in all the specimens, it is fair to suppose them really oblique to the axis of the shell, but how much so it is impossible to say. The siphon I have lately seen. It is very large, and a good deal excentric, but not quite lateral.

In the very close septa, and somewhat rugose character of the terminal portion, this differs from any Lower Silurian species with which I could compare it.

Locality.—UPPER TREMADOC. Garth: all the figures are from Mr. Homfray's cabinet.

Orthoceras vagans, Salter.

Pl. 24, figs. 1-5.

Quart. Geol. Journal, vol. 5, pl. 6, fig. 6. Siluria, 2nd ed., p. 219. Foss. 40, fig. 1.

One of the very few fossils common to the British and central European areas. Except this rather remarkable species, and the still more widely diffused

Bellerophon bilobatus, I hardly know a fossil common to the Lower Silurian beds of the two areas. The trilobites, spiral shells, and even most of the *Brachiopods*, are all distinct in the Lower Silurian period; while many species are identical in the Upper Silurian in the two regions. (Barrande, *passim.*)

The species grows to a large size; specimens 1¼ inches broad occur, and as the species tapers very slowly, this indicates a length of at least 18 or 20 inches. It is smooth, tapers very gradually in youth and mid-age, but is more conical when old. The septa are broad elliptic, oblique on the longer axis, moderately distant in the young shell, more than their diameter apart in middle age, and less than one-fourth their diameter apart when old. They are deeply cup-shaped, and the siphon is as nearly central as possible. The last chamber is unusually long. The remote septa, and broad oval, instead of round section, while the siphon keeps a central place, easily distinguishes this common smooth species from other Silurian shells. It were to be wished all described fossil *Orthocerata* had as good claims to specific distinction. But they are in general sad puzzles to the describer.

Localities.—CARADOC. Rhiwlas and other places near Bala; Coniston limestone of Westmoreland.

Orthoceras, sp.

Pl. 24, fig. 6.

It is unsafe to name so imperfect a fragment. Yet the species is noteworthy, as being a large one, probably 15 inches long, of quite circular form, and with a thick shell. The septa are only moderately distant.

Locality.—CARADOC. Rhiwlas, Bala.

Orthoceras audax, n. sp.

Pl. 24, fig. 7.

Probably three inches long, and half an inch broad (last chamber lost). Section broad oval. Siphon? Septa nearly direct, equidistant, close set, 6–7 in the space of a diameter.

Our figure represents the septa too oblique. They are nearly direct across.

O. gregarium of M'Coy's Lower Silurian Fossils of Ireland, from the same Bala limestone at the Chair of Kildare, appears to be the same species. It has an oval (not a subcircular) section, and it is certainly not the Upper Silurian fossil so called. [Synops. Sil. Foss. Ireland, p. 9, pl. 1, fig. 5.]

Locality.—CARADOC. Rhiwlas, Bala, a locality rich in deep-water forms.

Cyrtoceras Sonax, n. sp.

Pl. 25, fig. 1.

C. magnum, subteres, lente curvum, striatum, *striis asperis* ***rectis, nonnullis prominulis. Septa modice approximata.*** *Sipho magnus,* ***internus.***

A fine shell, rather abundant in the Rhiwlas limestone, Bala. It must have measured fully eight or nine inches when complete, and has a diameter at the mouth of 2½ inches by 2, the sides being compressed, and the section broad oval. The curve is gentle, the lines of growth nearly direct across, not arched downwards either on the back or front; they are somewhat roughly imbricate, but not regularly so. They are coarse raised threads, about eight in three lines; and occasionally interrupted by somewhat more prominent ridges. The septa are also nearly direct, but a little curved upwards towards the convex dorsal margin. They are moderately convex, and about three lines distant in a diameter of 1½ inch. The siphuncle is large and placed close to the inner* border (fig. 1 *a*). The shell probably thin.

We have the means of completing (or nearly so) the form of this species, by reference to smaller specimens in the same locality. It is very slightly curved, compared with the next, and is besides less compressed.

Locality.—CARADOC. Rhiwlas, Bala.

* This is really the dorsal margin, as we learn from *Nautilus*, but the ordinary nomenclature gives the convex edge for the back.

Cyrtoceras atramentarium, n. sp.

Pl. 25, figs. 2, 3, 4.

C. medium, compressum, (2 × 3), *curvum*, (*striatum?*) *Septa approximata, obliqua, curvata. Sipho internus.*

A smaller, much more curved, and more compressed fossil than the last. Its diameter front and back is rather more than 1¼ inch, and from side to side one inch. The proportion therefore is as three to two. The section is nearly a true oval, scarcely so much narrowed on the back as in our figure, and the siphon, not very large, is nearly internal.

The sharp lines of growth (not plain in our specimens) curve much backward, while the septa curve forward toward the back. They are considerably more oblique than in *C. sonax*, and this is the more conspicuous from the stronger curve of the shell. Their course is nearly direct for a third across, then bent rather than curved, and passing obliquely forward to the dorsal margin. At one inch diameter there are seven septa to the inch on the outer margin; they are crowded on the inner edge. The last chamber appears to be about as long as broad, its margin oblique following the lines of growth (in *C. Sonax* it is direct).

Locality.—CARADOC. Bala.

Cyrtoceras præcox, n. sp.

Pl. 10, fig. 3.

About an inch long, conical, gently curved, the mouth very oblique, the inner (dorsal?) margin being the prominent one. The septa, which follow the same curve, from within outwards, are placed very near together, four chambers in the space of one-tenth of an inch.

The shell was evidently a thin one. It is the earliest of the *Cephalopods* known, and it is not a little remarkable that the first species we meet with in ascending order should be—not *Orthoceras*, which is the most diffused and persistent form, but a genus which, so far as we know, is only Silurian and Devonian.

Locality.—LOWER? TREMADOC SLATE. Llanerch, W. of Portmadoc (Mr. Ash).

Lituites planorbiformis, Conrad.

Pl. 25, fig. 5.

See Appendix Pal. Foss. Woodw. Mus., p. 8, and M'Coy, ib., p. 324.

We have figured a small portion only, formerly found by Professor Sedgwick and myself at Bala, and described at length by Professor M'Coy and myself. Better specimens since obtained show four or five smooth whorls.

Locality.—CARADOC. Cwm Cymmerig, Bala (fig. 5). Complete casts at Twll-du, above Cwm Idwal, in the upper beds, at the crest of the pass, between the trappean layers.

J. W. S.

June 1865.

I am sorry to close this Appendix without some attempt to correlate the Welsh strata, by their fossils, with their exact equivalents in N. and S. America, Sweden and Norway, Bohemia, France and Spain, India and Australia. The materials for such an essay are extant, but the time is not at my own disposal. Etage C of Barrande is equivalent to our Lingula flag; and Etage D to our whole Llandeilo and Caradoc series.

I may, however, say that I regard the Quebec group of Canada as equivalent to our Tremadoc and Lower Llandeilo beds, and that the Regio BC of Angelin corresponds very nearly to the same horizon. The comparisons by Barrande, now so actively resumed by that admirable paleontologist, will give closer insight into the real relations of the lower beds of the Bohemian basin with our own. It is not for me in a mere note to anticipate his work.

Upper Llandovery Rocks.

Though the Upper Llandovery rocks have not been observed by the Geological Survey in North Wales, it is well to give a conspectus of the species found in South Wales, Shropshire, and other districts, in order to complete our view of the Silurian formations, of which a sketch for all Wales and Shropshire has been given in Chapters I. and II. Accordingly, Mr. Etheridge has drawn up the following list. For the numbers of these fossils that pass into the underlying and overlying strata, see page 231.

Upper Llandovery or May Hill Fossils.

Name.	Localities in Wales and Shropshire.
Cœlenterata (Zophyta).	
Omphyma turbinata, M. Edw.	Marloes Bay; Pembrokeshire.
Strephodes	Castell-craig-Gwyddon; Llandovery.
Palæocyclus porpita, Linn.	May Hill; Tortworth.
P. præacutus, Lonsd.	Malvern Hills.
Petraia elongata, Phill.	Castell-craig-Gwyddon; Pen-y-lan; Presteign; May Hill; Tortworth; Norbury, &c.
P. Æquisulcata, M'Coy	Builth.
P. uniserialis, M'Coy	Castell-craig-Gwyddon, S.E. of Llandovery.
P. subduplicata, M'Coy	Pen-y-lan; Llandovery; Builth; Presteign; May Hill; Church Stretton; Malverns.
P., var. *crenulata*, M'Coy	Castell-craig-Gwyddon; Abberley Hills; May Hill; Norbury.
P., sp. (*reticulata* (MSS.)	Pen-y-lan; Llandovery.
P. bina, Lonsd.	May Hill; Tortworth; Norbury; Malverns.
Halysites catenularius, Linn.	Castell-craig-Gwyddon and Pen-y-lan; Llandovery; May Hill.
Heliolites interstinctus, Wahl.	May Hill; Malverns.
H. megastoma, M'Coy	Malverns.
Favosites multipora, Lonsd.	Castell-craig-Gwyddon.
F. alveolaris, Blainv.	Castell-craig-Gwyddon; Pen-y-lan; Chirbury; Tortworth; Malverns; Church Stretton.
F. cristata, Blum.	Malverns.
F. aspera, D'Orb.	Do.
Stenopora fibrosa, Goldf.	Llandovery; Wooltack; Marloes Bay; May Hill; Tortworth.
Echinodermata.	
Palæaster coronella, Salt.	Malvern.
Echinocystites (*Palæchinus*) *Phillipsiæ*, Forbes.	Worcester Beacon; Malverns.
Glyptocrinus, sp.	Llangodock.
Periechocrinus, sp.	Tortworth.
Numerous portions of stems and arms of unknown forms occur in many localities.	Pen-y-lan; Builth; Llangadock; Castell-craig-Gwyddon.
Annelida.	
Tentaculites anglicus, Salt.	Presteign; Wooltack and Marloes Bay; Malvern; Tortworth; Norbury; Church Stretton.
Cornulites serpularius, Schloth.	Marloes Bay; Wooltack; Malverns; Chirbury; Church Stretton.

Name.	Localities in Wales and Shropshire.
Crustacea.	
Calymene Blumenbachii, Auct.	Pen-y-lan; Llandovery; Presteign; Norbury; Longmynd; Chirbury; Church Stretton; Malverns.
Illænus Barriensis, Murch.	Malverns?
I. Thomsoni, Salt.	Builth; Onny River; Presteign; Pen-y-lan.
I. Bowmanni, Salt.	Llandovery; Chirbury?
Encrinurus punctatus, var. *Arenaceus*, Brunn.	Llandegle; Pen-y-lan; S. of Llandovery; Wooltack; Chirbury; Church Stretton; Walsall; Malverns; Tortworth; May Hill, &c.
Proetus latifrons, M'Coy	Castell-craig-Gwyddon; Malverns.
P. Stokesii, Murch.	Norbury; Malverns; Chirbury; Llandovery; Wooltack.
Phacops Weaveri, Salt.	Presteign; Tortworth.
P. Downingiæ, Murch.	Marloes Bay; Norbury; Bogmine.
P. imbricatulus, Angelin	Presteign.
P. caudatus, Brün.	Walsall.
P. Stokesii, Milne, Edw.	Llandovery; Wooltack; Tortworth; Chirbury; Norbury; Malverns; Walsall; Bogmine.
Acidaspis Brightii, Milne, Edw.	Castell-craig-Gwyddon; Llandovery.
Cheirurus bimucronatus, Murch.	Castell-craig-Gwyddon; Norbury.
Polyzoa or Bryozoa.	
Graptolithus priodon, Bronn.	May Hill; Tortworth.
Retiolites venosus, Hall	Pen-y-lan; Llandovery.
Fenestella subantiqua, D'Orb.	May Hill.
F. assimilis, Lonsd.	S.E. of Llandovery.
Ptylodictya lanceolata, Lonsd.	Church Stretton.
P. explanata, M'Coy	Ankerdine Hill; Llandovery.
P. scalpellum, Lonsd.	Malverns.
Brachiopoda.	
Pentamerus lens, Sow.	Builth; Llandovery; May Hill; Norbury; Chirbury.
P. liratus, Sow.	Malverns; May Hill; N.E. of Chirbury.
P. oblongus, Sow. (including *P. lævis*, Sow.)	Builth; Pen-y-lan; Landovery; Presteign; Malverns; Norbury; Church Stretton; Chirbury.
P. globosus, Sow.	Llandeilo; Malverns.
P. undatus, Sow.	Builth; Llandovery; Malverns; Church Stretton.
Rhynchonella decemplicata, Sow.	Presteign; Malverns; Minton; Chirbury; Norbury; Church Stretton.
R. nucula, Sow.	Marloes Bay.
R. pusilla, Sow.	Malverns.
R. obtusiplicata, Hall	Presteign; Llandovery; May Hill; Worcester Beacon; Bogmine.
R. sexcostata, M'Coy	Huntley Hill; Walsall.
R. borealis, Schloth	Chirbury; Malverns.
R. navicula, Sow.	May Hill.
R. Grayii, Dav.	Glansevin, near Llandovery.
R. didyma, Dalm.	Glansevin; Llandovery.
(*Athyris*) *Merista tumida*, Dalm.	May Hill.
Lingula, sp.	Wooltack Park, Pembrokeshire.
L. crumena, Phill.	Malverns.
L. parallela, Phill.	Do.
L. Symondsii, Salter	Pen-y-lan.

Name.	Localities in Wales and Shropshire.
***Strophomena depressa*, Dalm.**	Builth; Pen-y-lan; Llandovery; Chirbury; Norbury; Malverns; May Hill.
***S. bipartita*, Salter**	Wooltack, Pembrokeshire.
***S. arenacea*, Salt., MSS.**	Presteign; May Hill; Malverns; Tortworth; Church Stretton, &c.
***S. simulans*, M'Coy**	Malverns.
***S. pecten*, Linn.**	S. of Llandovery; Builth; Church Stretton; Bogmine; May Hill.
***S. applanata*, Salt.**	Builth; Malverns.
***S. antiquata*, Sow.**	Llandovery; Bogmine.
***S. compressa*, Sow.**	Presteign; Marloes Bay; Norbury; Chirbury; Tortworth; Malverns.
***S. englypha*, Dalm.**	Pen-y-lan, Llandovery.
***Orthis reversa*, Salt.**	Llandovery; Malverns; Tortworth; Chirbury; Norbury; Bogmine.
***O. Calligramma*, Dalm. (chiefly var. *Davidsoni*).**	Presteign; Llandovery; Builth; Longwynd; Chirbury; May Hill; Malverns.
***O. elegantula*, Dalm.**	Llandovery; Presteign; Wooltack; Chirbury; Bogmine; Norbury; Malverns; May Hill; Church Stretton.
***O. biforata*, Schloth**	Presteign; Bogmine.
***O. biloba*, Linn.**	Mwmfre.
***O. porcata*, M'Coy**	Llandovery.
***O. lata*, Sow.**	Wooltack Park.
***O. triangularis*, Sow.**	Llandovery; Castell-craig-Gwyddon.
***Leptæna transversalis*, Dalm.**	Builth; N. of Llandovery; Pen-y-lan; Llangadock; Malverns; Longwynd; Norbury; Chirbury.
***L. Grayii*, Davidson**	Llangadock.
***L. scissa*, Salt., MSS.**	Builth; Cefn-craig-Gwyddon.
***L. quinquecostata*, M'Coy**	Llandovery.
***L. lævigata*, Sow.**	Devil's Bridge.
***Chonetes lata*, V. Buch.**	Wooltack; Tortworth.
***Atrypa marginalis*, Dalm.**	Landovery; Chirbury.
***A. reticularis*, Linn.**	Mandwain; Llandovery.
***A. hemisphæerica*, Sow.**	Llandeilo; Builth; Llangadock; Presteign; Castell-craig-Gwyddon; Malvern; May Hill; Tortworth; Longwynd; Church Stretton; Norbury; Chirbury.
***Spirifer trapezoidalis*, Dalm.**	Tortworth; Chirbury; Malverns; S.E. of Llandovery; Builth.
***S. elevatus*, Dalm.**	Marloes Bay; Tortworth; Malverns.
***S. plicatellus*, Linn.**	Llangadock; May Hill; Norbury.
LAMELLIBRANCHIATA.	
***Pterinea retroflexa*, Wahl.**	Marloes Bay; Norbury; Chirbury.
***P. planulata*, Conrad**	Glansevin; Llandovery.
***P. demissa*, Conrad**	Malverns.
***Ctenodonta deltoidea*, Phill.**	Do.
***C. Eastnori*, Sow.**	Do.
***C. lingualis*, Phill.**	Do.
***C. rhomboidea*, Phill.**	Do.
***C. subæqualis*, Sow.**	Do.
***Mytilus mytilimeris*, Conrad**	May Hill.
***Modiolopsis antiqua*, Sow.**	Marloes Bay; Church Stretton ?
***Actinodonta cuneata*, Phill.**	Marloes Bay.
***Orthonota inornata*, Phill.**	Do.
***O. amygdalina*, Sow.**	Tortworth.

Name.	Localities in Wales and Shropshire.
GASTEROPODA.	
Natica, sp.	Norbury; Bogmine.
Acroculia Haliotis, Sow.	Chirbury; Norbury; Church Stretton.
Cyclonema crebristria, M'Coy	Presteign; Cefn-craig-Gwyddon.
Euomphalus funatus, Sow.	Marloes Bay; May Hill.
E. sculptus, Sow.	May Hill; Tortworth.
E. prænuntius, Phill.	May Hill.
Trochus multitorquatus, M'Coy	Marloes Bay.
Holopella cancellata, Sow.	Presteign; Chirbury; Norbury; Bogmine.
H. obsoleta, Sow.	Bogmine.
Pleurotomaria fissicarina, Phill.	Malverns.
P. gugosa, Phill.	Pen-y-lan; Castell-craig-Gwyddon; Norbury.
Murchisonia simplex, M'Coy	Bogmine; Norbury.
Raphistoma lenticularis, Sow.	Marloes Bay; Norbury; Church Stretton.
Macrocheilus fusiformis, Sow.	Presteign.
Turbo tritorquatus, M'Coy	Pen-y-lan; Llandovery; Church Stretton.
HETEROPODA.	
Bellerophon bilobatus, Sow.	Malverns.
B. dilatatus, Sow.	Presteign; Gorllwynfach; Church Stretton.
B. expansus, Sow.	Norbury; Bogmine.
B. trilobatus, Sow.	Llangadock; Marloes Bay; Bogmine.
PTEROPODA.	
Ecculiomphalus lævis, Sow.	Church Stretton.
CEPHALOPODA.	
Orthoceras filosum, Sow.	Do.
O. tenuistriatum, Sow.	Haverfordwest.
Tretoceras bisiphonatum, Sow.	Gorllwynfach.
Lituites cornu-arietis, Sow.	Presteign.

LIST of FOSSILS from the UPPER LLANDOVERY ROCKS of the BOGMINE near SHELVE.

At the Bogmine, near Shelve in Shropshire, there is a small outlying patch of fossiliferous grit. It lies unconformably on the Llandeilo flags, and physically may be considered an undoubted outlier of the Upper Llandovery rocks that skirt the base of the Cambrian rocks of the Longmynd and the adjacent Lower Silurian strata. The whole having been formed during a period of submergence, the outlier may be of slightly later date than the Upper Llandovery rocks at the base of the hill, even though they were originally continuous. In that case the patch at the Bogmine during the later stage of the submergence of the Old Silurian and Cambrian land, was still a marginal deposit, while the continuation of the same formation, formed at an earlier period of the submergence, was out at sea in deeper water.

The following list of fossils bears out this view.

CŒLENTERATA.

Omphyma turbinatum, M. Edw.
Petraia bina, Lonsd.
Favosites.

ANNELIDA.

Tentaculites anglicus, Salt.
Cornulites serpularius, Schloth.

CRUSTACEA.

Calymene brevicapitata, Port.
Illænus Barriensis, Murch.
Proetus Stokesii, Murch.
Phacops Downingiæ, Murch.
P. Stokesii, M. Edw.

POLYZOA.

Fenestella subantiqua.

BRACHIOPODA.

Rhynchonella obtusiplicata, Hall.
R. borealis, Schloth.
Strophomena pecten, Sow.
S. antiquata, Sow.
S. compressa, Sow.
Orthis reversa, Salt.
O. testudinaria, Dalm.
O. elegantula, Dalm.
O. biforata, Schloth.
O. radians, Sow.
Atrypa cassa, Sow.
Leptæna lævigata, Sow.

LAMELLIBRANCHIATA.

Pterinea retroflexa, Wahl.
Goniophora cymbæformis, Sow.
Mytilus mytilimeris, Conrad.

GASTEROPODA.

Natica, *sp*.
Holopella cancellata, Sow.
H. obsoleta, Sow.
Raphistoma lenticularis, Sow.
Turbo tritorquatus, M'Coy.

HETEROPODA.

Bellerophon expansus, Sow.
B. trilobatus, Sow.
B. carinatus.
B. dilatus, Sow.

CEPHALOPODA.

Lituites cornu-arietis, Sow.
Orthoceras.

GENERAL INDEX.

N.

O.

P.

INDEX TO APPENDIX.

The Index to the Appendix has been compiled by Mr. Etheridge, and care has been taken to give reference to every locality and genus, and to authors mentioned in the text, so as to render this Index as valuable as possible so far as the organic remains and their geographical distribution is concerned. A List of the Contents of the Plates is also given, it being in this form easier for reference than if embodied in the General Index.

A.

B.

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V.

W.

LIST AND CONTENTS OF PLATES.

Theca, three new species; figs. 14–21.
——— (Cleidotheca) operculata, *Salter*; figs. 22–24.
——— (Centrotheca) cuspidata, *Salter*; fig. 25.

PLATE 11A.

Lower Llandeilo.

Diplograpsus, *various* sp.; figs. 1–3, 4–6.
Graptolites sagittarius, *His.*; fig. 2.
Dendrograpsus furcatula, *Salter*; fig. 5.
Agnostus; fig. 7.
Homalonostus bisulcatus, *Salter*; fig. 8.
Dionide atra, *Salter*; fig. 9.
Æglina caliginosa, *Salter*; fig. 13.
Conularia, two species; figs. 11, 12.
Palæarca socialis, *Salter*; fig. 13.

PLATE 11B.

Lower Llandeilo.

Illænus; figs. 1, 2.
Æglina binodosa, *Salter*; fig. 3.
Trinucleus Murchisoni, *Salter*; fig. 4.
Ogygia Selwynii, *Salter*; fig. 5.
Didymograpsus; figs. 6–8.
Cyathocrinus; fig. 9.
Lingula plumbea, *Salter*; fig. 10.
Orthis, two species; figs. 11–14.
Cucullella anglica, *Salter*; fig. 15.
Ribieria complanata, *Salter*; fig. 16.
Palæarca amygdalus, *Salter*; fig. 17.
Orthoceras, two species; figs. 18–20.
Ophileta; fig. 21.
Theca simplex, two species; figs. 22–26.
Worm burrows (scolithus); fig. 27.

PLATE 12.

Lower Llandeilo.

Diplograpsus, two species; figs. 1, 1a.
Annelide burrows; fig. 2.
Calymene parvifrons; fig. 3.
Asaphus affinis, *M'Coy*; fig. 4.
Orthis calligramma, *Dalm.*; fig. 5.
Obolella; figs. 6, 7.
Ogygia peltata, *Salter*; fig. 8.
Trinucleus, two species; figs. 9, 10.
Æglina, two species; figs. 11, 12.

PLATE 13.

Llandeilo flags.

Asaphus tyrannus, *Murch.*; figs. 1–7.
Agnostus M'Coyii; fig. 8.
Trinucleus favus, *Salter*; fig. 9.
Orthis striatula, *Conrad*; figs. 10–14.

PLATE 14.

Caradoc or Bala beds.

Annelide tubes; figs. 1–4.
Fucoids; figs. 5, 6.

PLATE 15.

Caradoc or Bala beds.

Asaphus Powsii, *Murch.*

PLATE 16.

Caradoc or Bala beds.

Homalonotus bisulcatus, *Salter*; figs. 1–8.
——— rudis, *Salter*; figs. 9–11.

PLATE 17.

Caradoc or Bala beds.

Calymene Blumenbachii, *Brong.*; figs. 1–7.
——— var. brevicapitata, *Portlock*; figs. 8–12.
——— cambrensis, *Salter*; figs. 13, 14.
——— duplicata, *Murch.*; figs. 15–20.

PLATE 18.

Caradoc or Bala beds.

Cheirurus juvenis, *Salter*; figs. 1, 2.
——— Octolobatus, *M'Coy*; fig. 3.
——— bimucronatus, *Murch.*; figs. 4, 5, 6, 7.
Illænus Bowmanni, *Salter*; fig. 9.
——— Davisii, *Salter*; fig. 9.

PLATE 19.

Caradoc or Bala beds.

Lichas laxatus, *M'Coy*; figs. 1–2.
Trinucleus concentricus, *Eaton*; fig. 4.
Encrinurus sexcostatus, *Salter*; figs. 5, 6.
——— venucosus, *Delwar.*; fig. 7, *head.*
Agnostus trinodus, *Salter*; fig. 8.
Beyrichia complicata, *Salter*; fig. 9.
Nebulipora favulosa, *Phill.*; fig. 10.
Orthis alternata, *Sow.*; figs. 11–13.
——— porcata, *M'Coy, var. retrorsa*; fig. 14.

PLATE 20.

Caradoc or Bala.

Sphæronites pyriformis, *Forbes*; figs. 1, 2.
——— munitus, *Forbes*; fig. 3.
——— Litchii, *Forbes*; fig. 4.
Pleurocysites Rugeri, *Salter*; fig. 5.
Sphæronites stelluliferus, *Salter*; fig. 6.
——— punctatus, *Forbes*; fig. 7.
Echinosphærites Arachoideus; fig. 8.
——— Davisii, *M'Coy*; fig. 9.
——— Balthicus, *Eichew*; fig. 10.
Hemicosmites oblongus, *Pander*; fig. 11.
——— rugatus, *Forbes*; fig. 12.
Agelacrinus Buchianus, *Forbes*; fig. 13.

PLATE 21.

Caradoc or Bala beds.

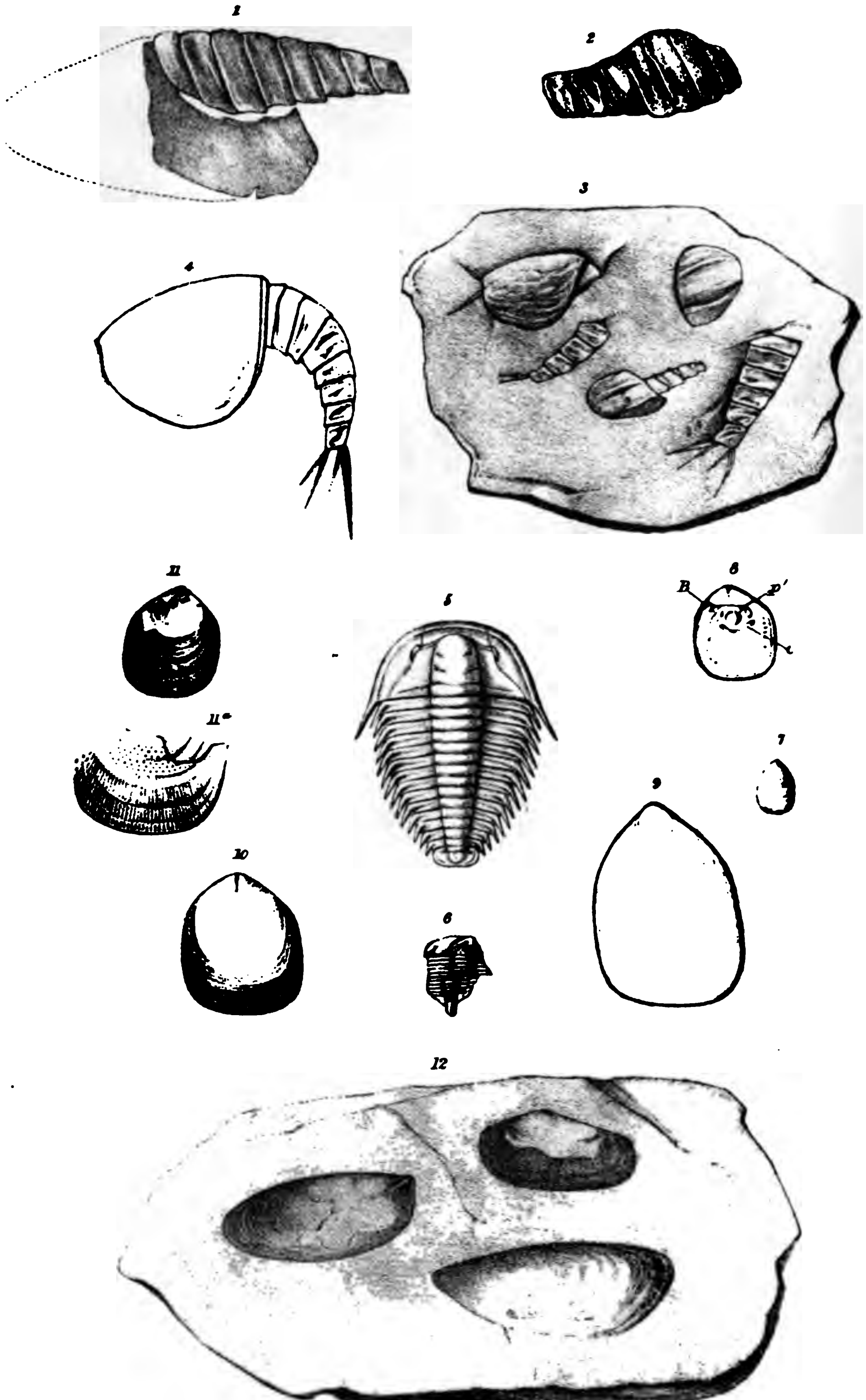
Orthis actoniæ, *Sow.*; figs. 1–8.
——— flabellalum, *Sow.*; figs. 9, 16.

PLATE 22.

Caradoc or Bala beds.

Orthis calligramma, *Dalm.*, var. Proava; fig. 1.

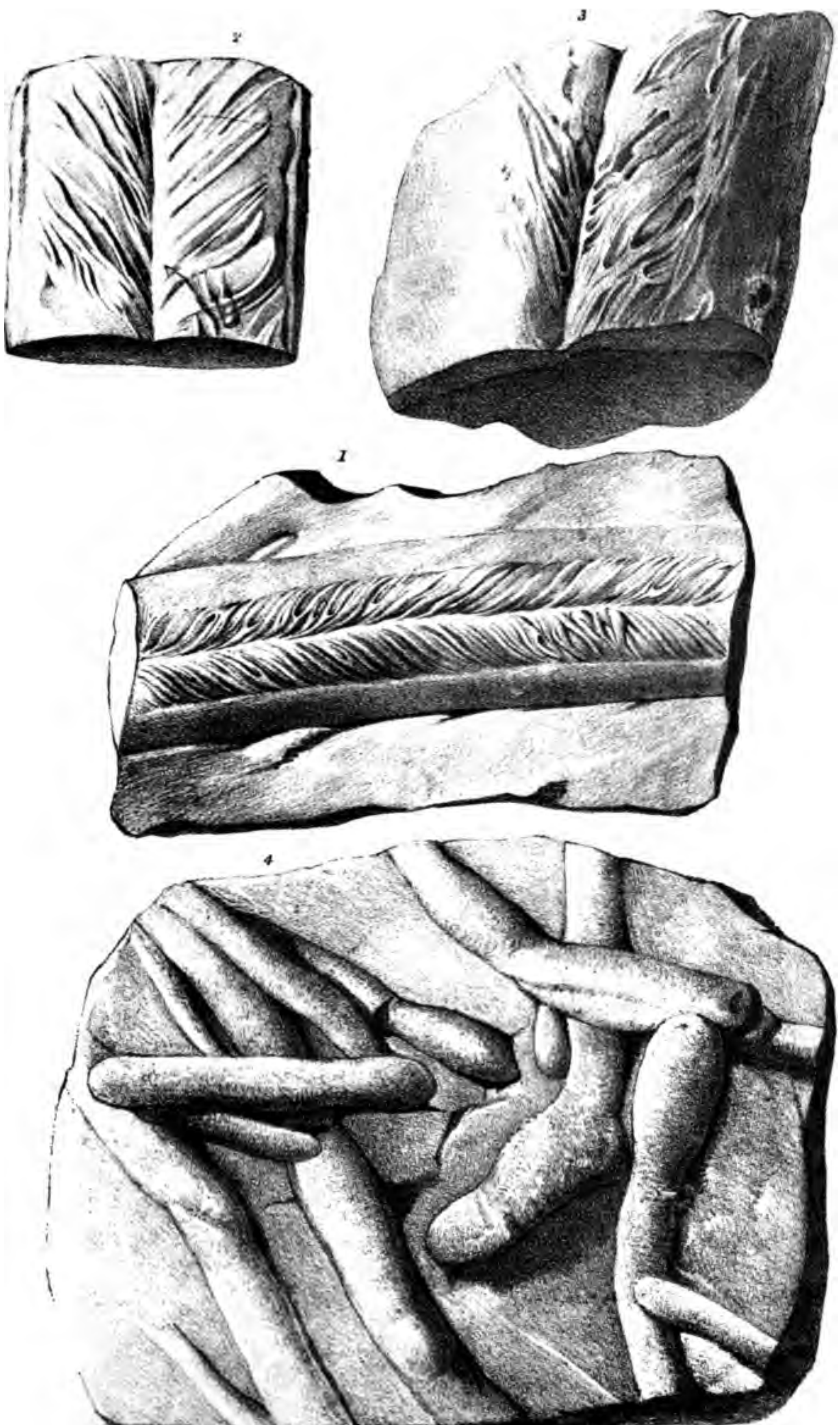
Tracks, probably made by the
HYMENOCARIS vermicauda,
Tremadoc, N Wales.



C. R. Bone, lith. Day & Son lithrs to the Queen

1_4. HYMENOCARIS VERMICAUDA_*Salter*. 5.6.OLENUS MICRURUS...*Salter*

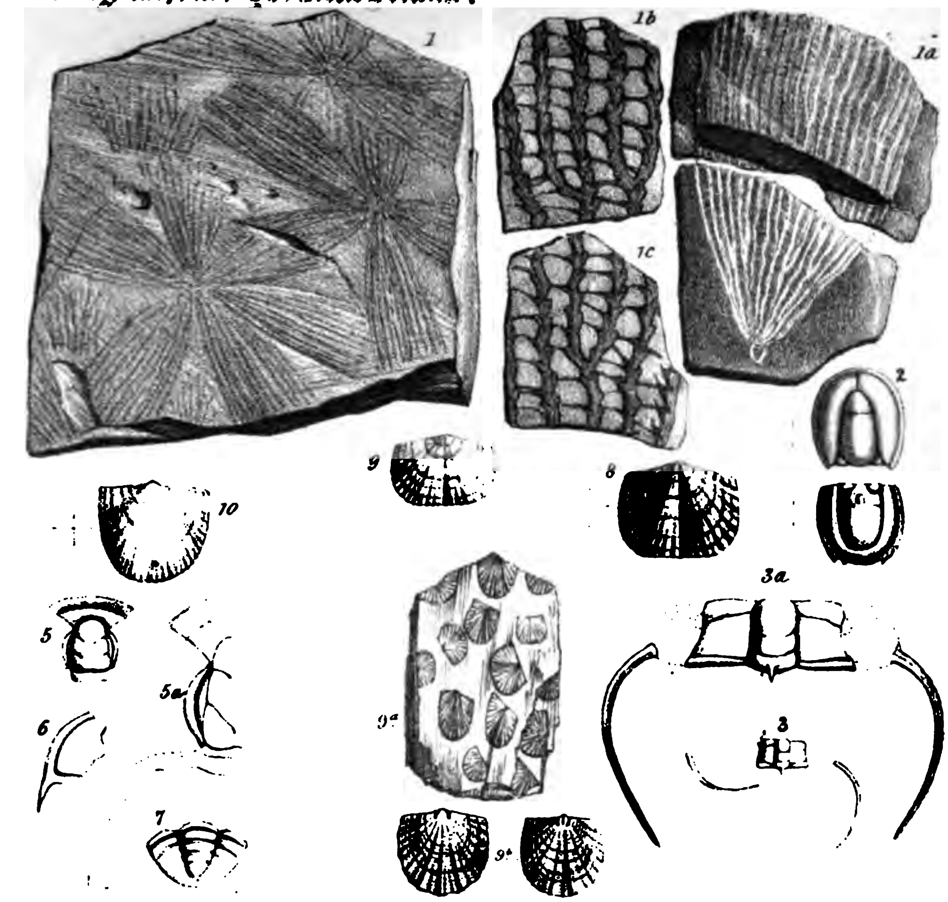
7_12 LINGULELLA DAVISII M'Coy



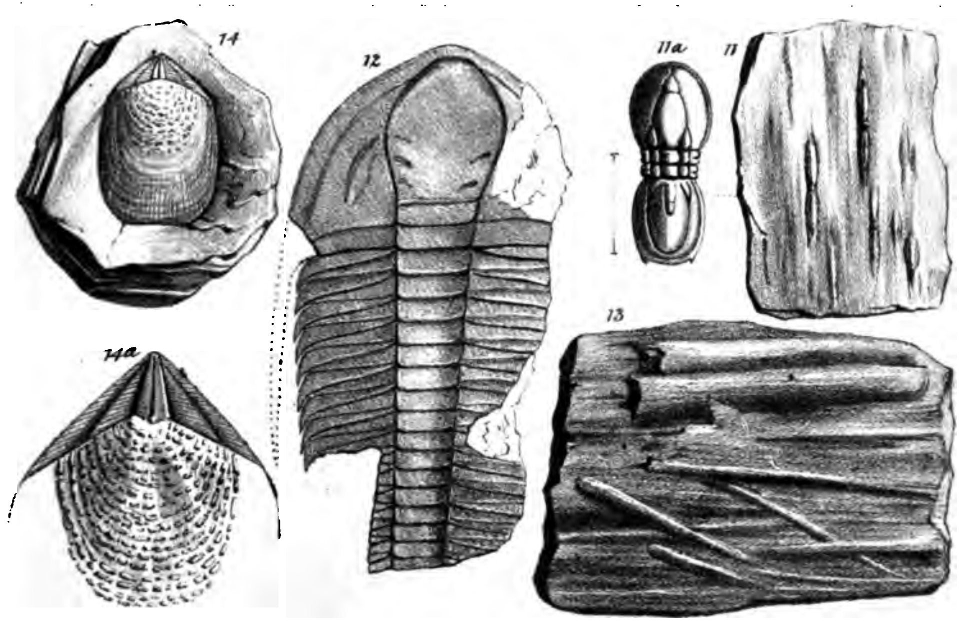
C. R. Bone lith — Day & Son lith^rs to the Queen

1_3 CRUZIANA SEMIPLICATA. *Salter* 4. ANNELIDE_ BURROWS (*Chondrites &c.*)

Geological Survey of Great Britain. LINGULA FLAGS.



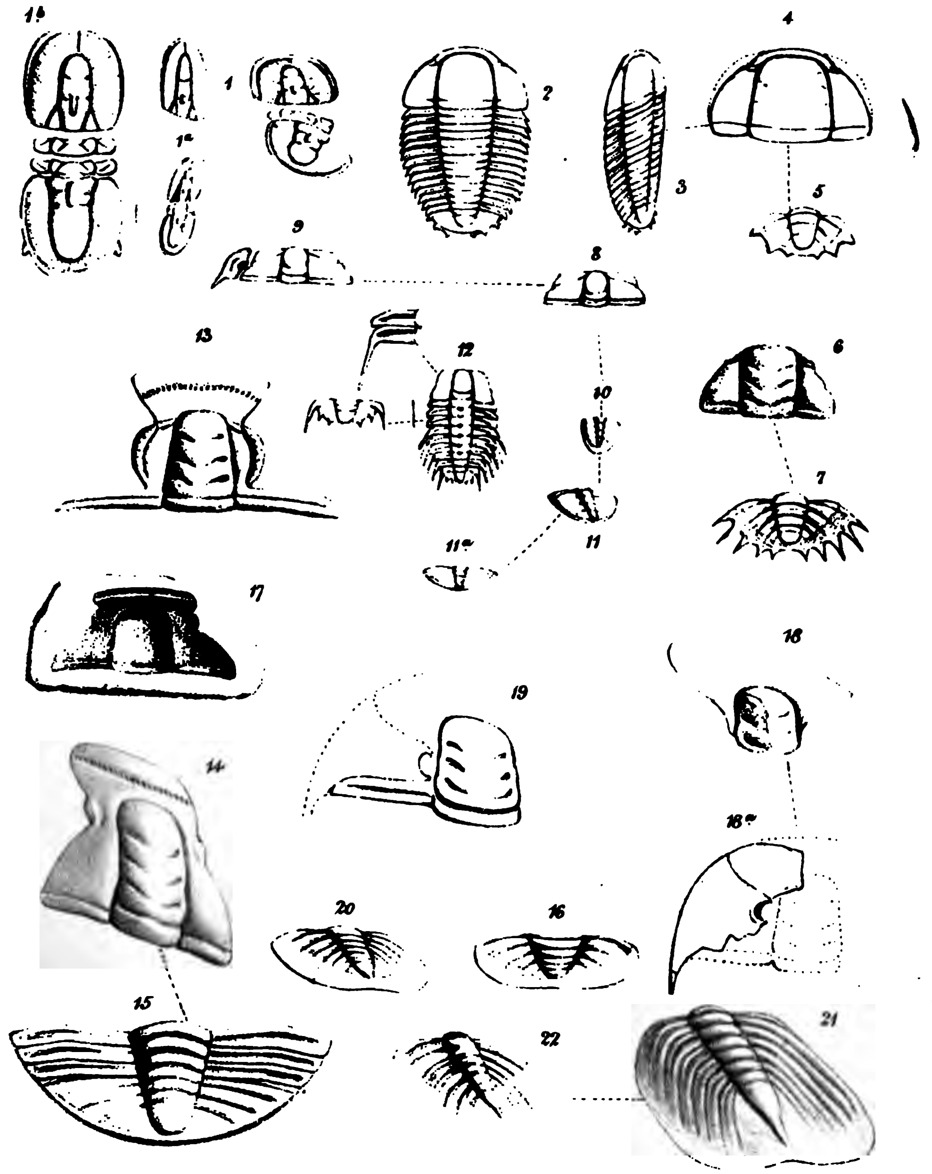
UPPER LINGULA FLAGS.



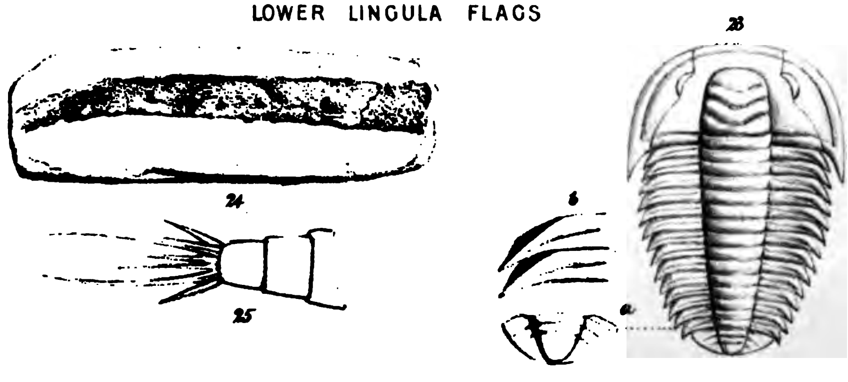
C.R. Bone, del. et lith. J.W. Salter, direxit. LOWER LINGULA FLAGS. Day & Son, Lith^rs to the Queen.

1.	DICTYONEMA SOCIALE — *Salter.*	8–10.	ORTHIS LENTICULARIS, *Dalm.*
2, 11.	AGNOSTUS PRINCEPS — *n. sp.*	12.	PARADOXIDES FORCHHAMMERI — *Ang?*
3, 4.	OLENUS ALATUS — *Boeck.*	13.	ANNELIDE BURROWS.
5–7.	CONOCORYPHE INVITA — *Salter.*	14.	LINGULELLA DAVISII — *M^c Coy.*

UPPER LINGULA FLAGS.

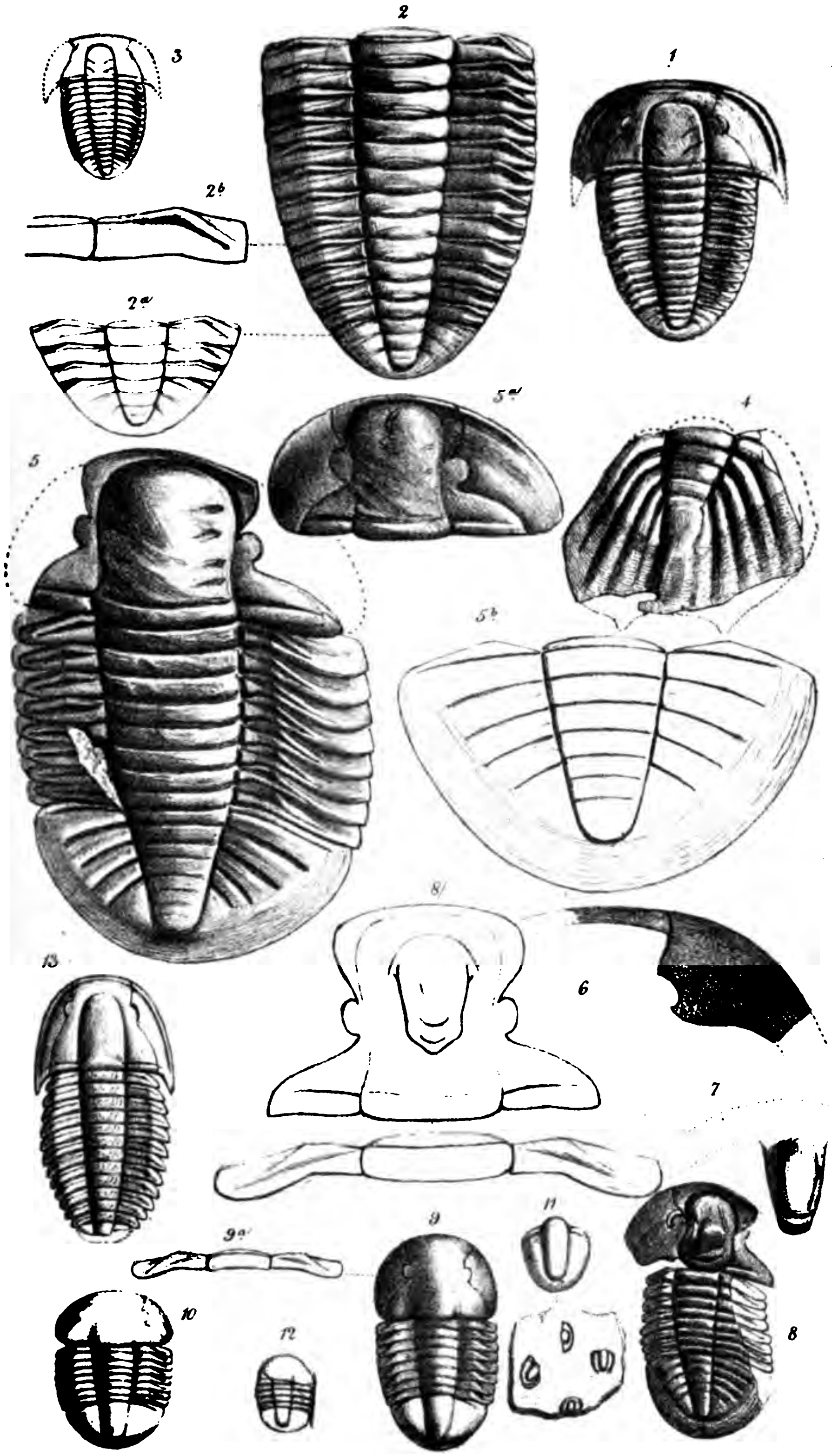


LOWER LINGULA FLAGS



C.R. Bone, del. et lith; J.W. Salter, direxit. Day & Son, Lith[rs] to the Queen

1. ACNOSTUS PRINCEPS, n. sp.
2_12 OLENUS_various species, new.
13_16 CONOCORYPHE, 3 species.
– CORYPHE? SIMPLEX, n. sp.
18_22 DIKELOCEPHALUS?_n. sp.
23. OLENUS CATARACTES_n. sp.
24. SCOLECODERMA TUBERCULATA, n. sp.
25. HYMENOCARIS VERMICAUDA, Salter.



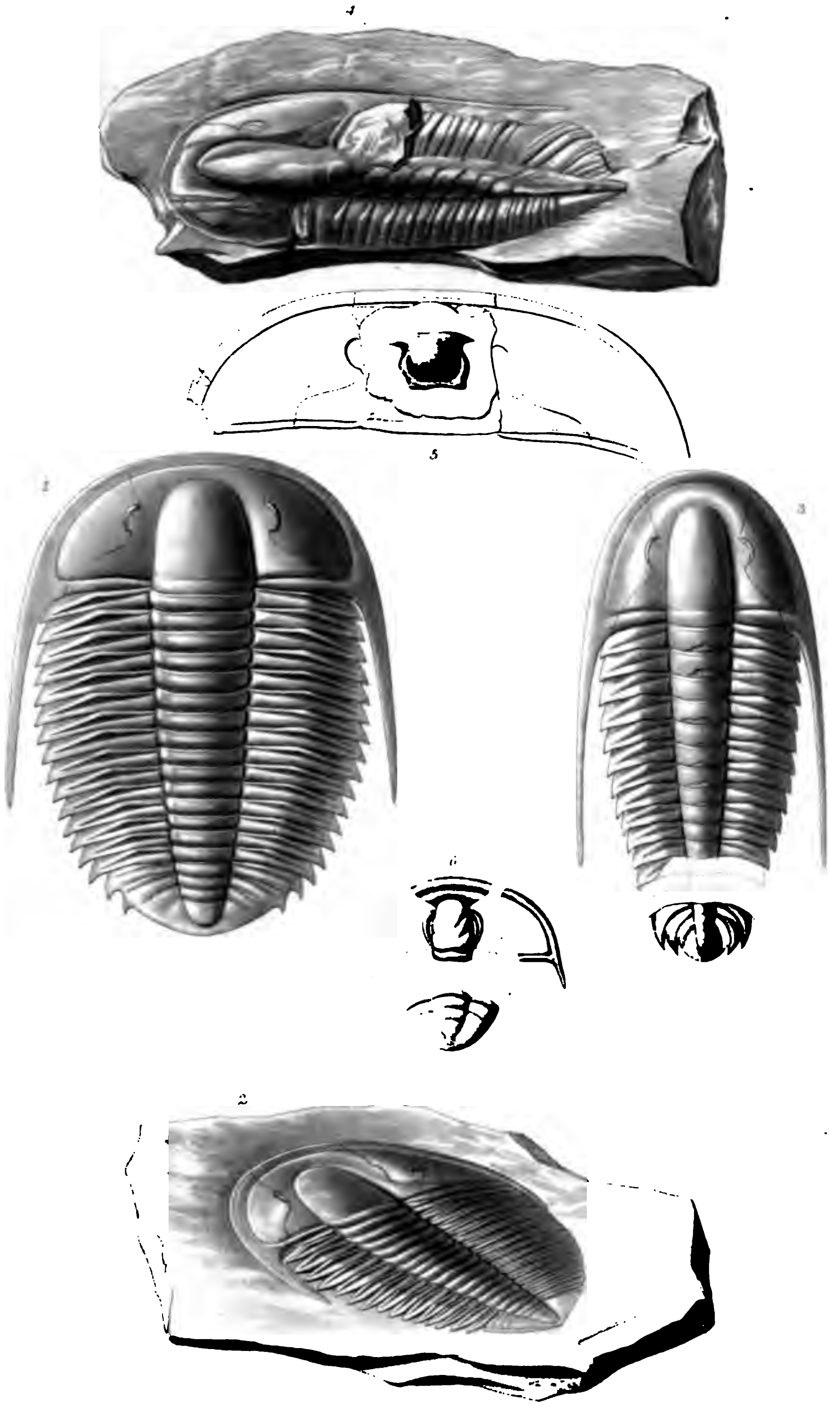
C.R. Bone, del. et lith. J.W. Salter direxit

Day & Son, Lithrs to the Queen

1_3. CONOCORYPHE DEPRESSA (Salter) | 5_8. NIOBE HOMFRAYI (n. s)
4. DIKELOCEPHALUS FURCA? (n. s) | 9_12. PSILOCEPHALUS INNOTATUS (n. s)
13. CONOCORYPHE VERISIMILIS (n. s)

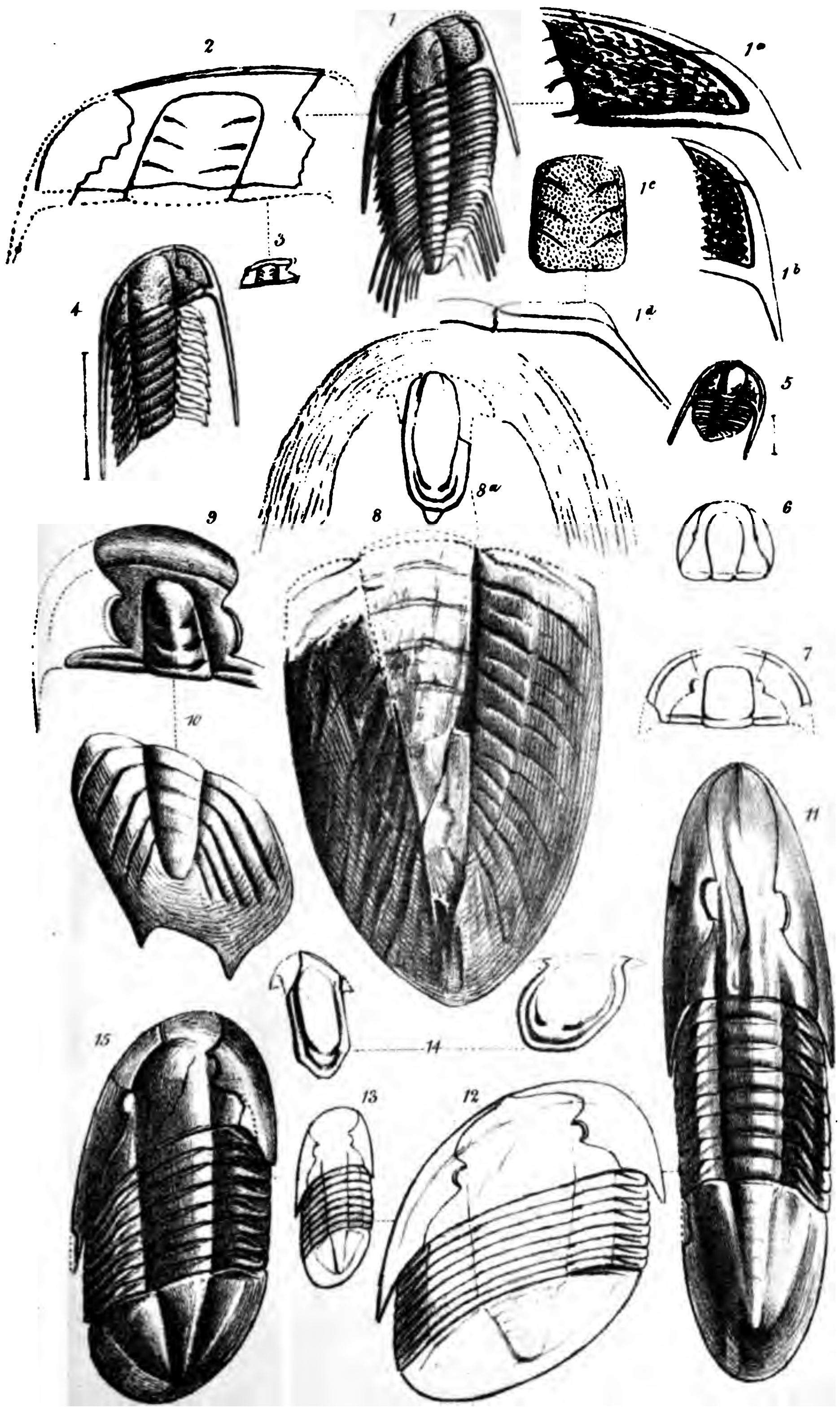
Geological Survey of the United Kingdom.

ANGELINA
Tremadoc Slate



1-5 ANGELINA SEDGWICKI *Salter* (*Tremadoc Slate*)

6 CONOCORYPHE INVITA *Id* (*Up. Lingula Flags*)

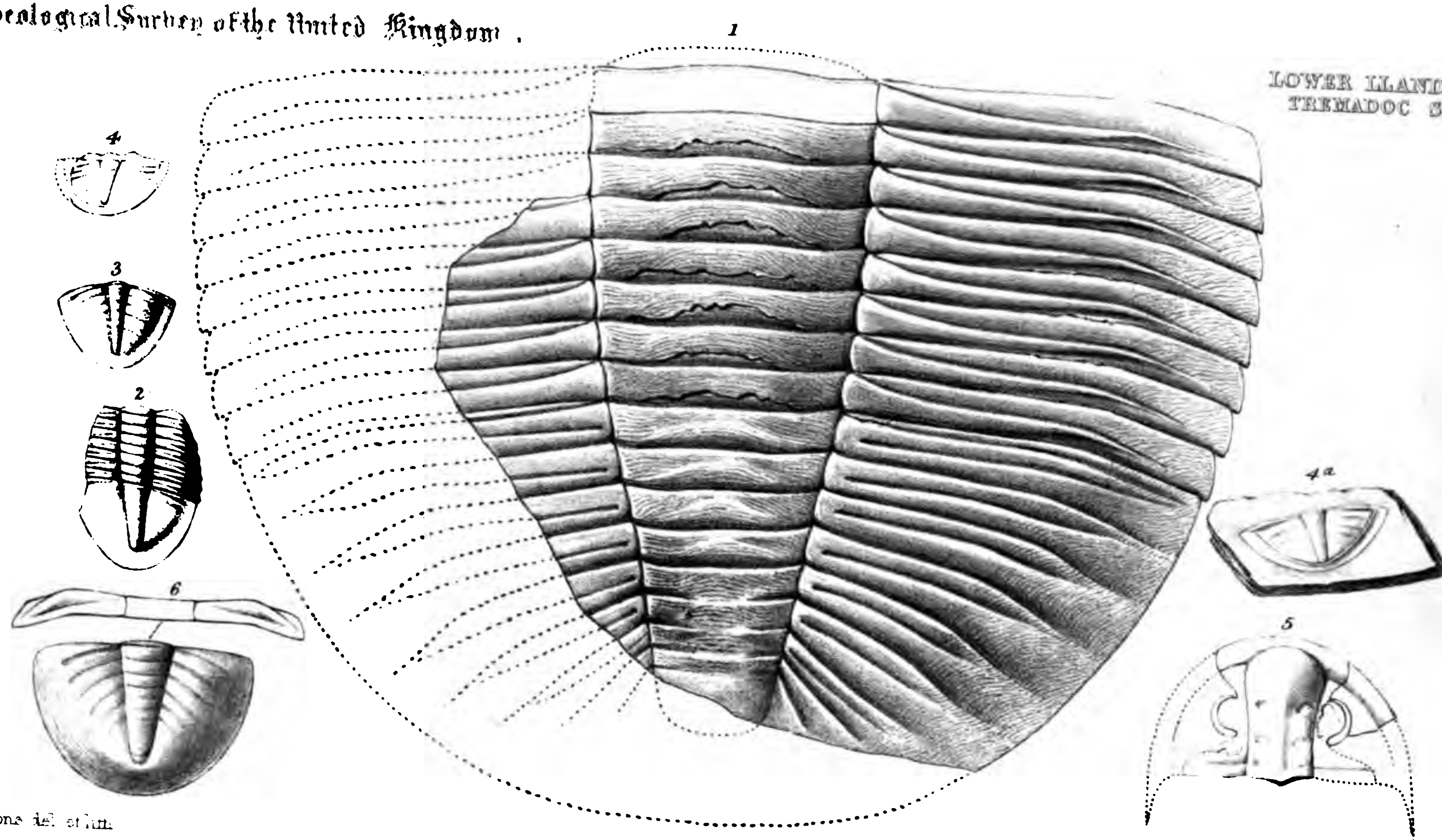


C. R. Bone, del. et lith. J. W. Salter, direxit. Day & Son, Lith^rs to the Queen.

1–3. CHEIRURUS FREDERICI (n. sp.)	8. OCYGIA SCUTATRIX (Salter)
4. OLENUS IMPAR (n. sp.)	9–10 DIKELOCEPHALUS FURCA (n. sp.)
5. AMPYX PRÆNUNTIUS (n. sp.)	11–14 ASAPHUS HOMFRAYI (n. sp.)
	AFFINIS (M^c Coy)

Geological Survey of the United Kingdom.

LOWER LLANDEILO or TREMADOC SLATES.



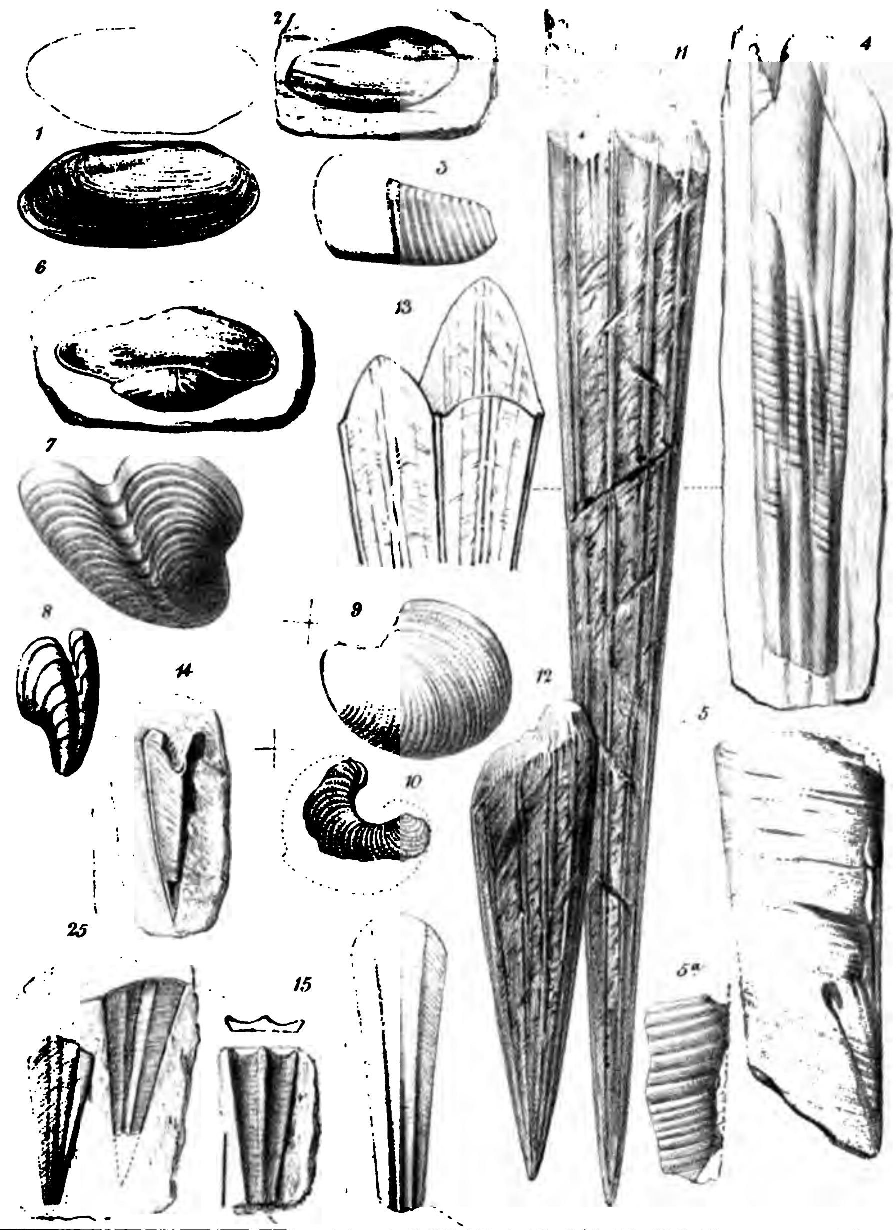
R C Bone del et lith.

Day & Son Lith.rs to The Queen.

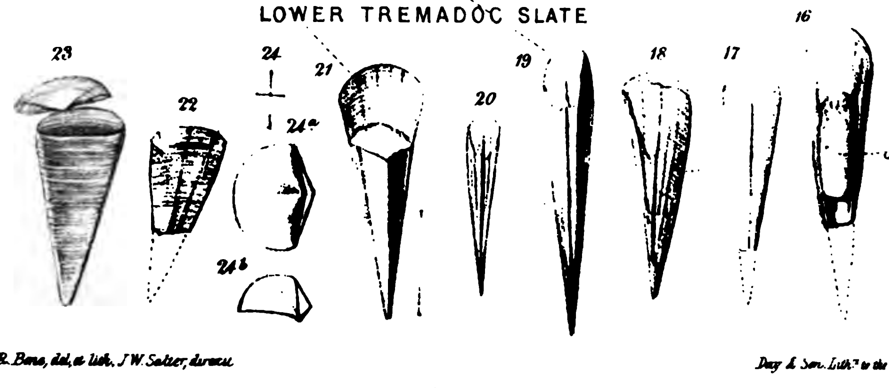
I. OGYGIA SCUTATRIX, *Salter*, 2–6. OGYGIA SELWYNII, *id.*

Geological Survey of the United Kingdom. (TREMADOC SLATE)

UPPER TREMADOC SLATE.

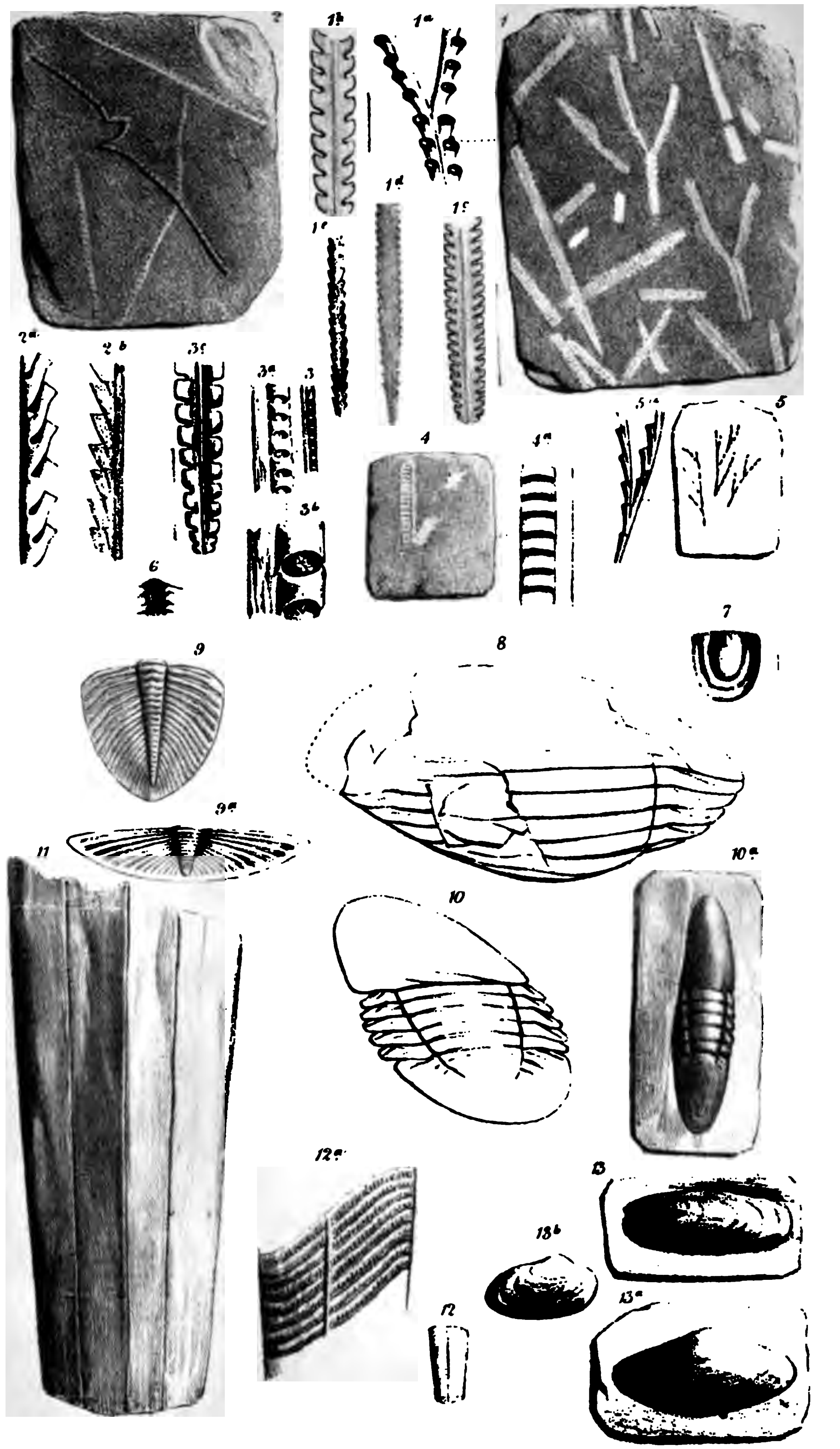


LOWER TREMADOC SLATE



C.R. Bone, del. et lith. J.W. Salter, direxit.　　Day & Son. Lith.rs to the Queen

1.2 LINGULOCARIS LINGULŒCOMES *n. sp*	11_13. CONULARIA HOMFRAYI *n. sp*
3. CYRTOCERAS PRŒCOX *n. sp*	14_21. THECA 3 *new sp*
4_5. ORTHOCERAS SERICEUM *n. sp*	22_24 THECA (CLEIDOTHECA) OPERCULATA *n. sp*
6_10. BELLEROPHON 2 *new sp*	25 THECA (CENTROTHECA) CUSPIDATA *n. sp*

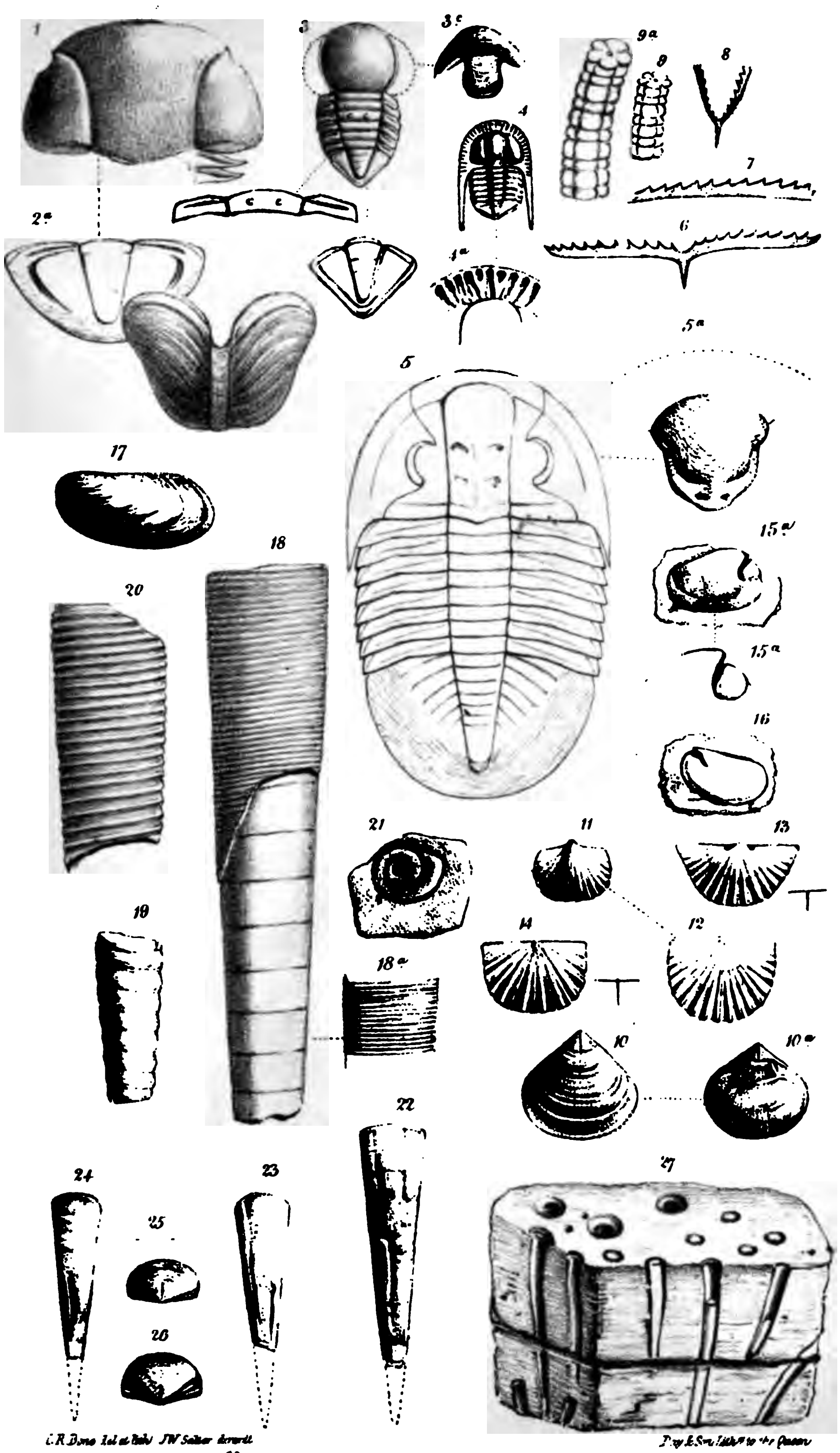


C. R. Bone del. et lith. J. W. Salter direxit — Day & Son, Lith^rs to the Queen

1.3.4.6. DIPLOGRAPSUS, *various sp.*
2. GRAPTOLITES SAGITTARIUS, *His.*
5. DENDROGRAPSUS FURCATULA, *n. sp.*
7. AGNOSTUS, *n. sp.*
8. HOMALONOTUS BISULCATUS *Salter?*
9. DIONIDE ATRA, *n. sp.*
10. ÆGLINA CALICINOSA, *n. sp.*
11.12. CONULARIA, *2 sp.*
13. PALÆARCA SOCIALIS, *n. sp.*

PLATE II

Geological Survey of the United Kingdom. (LOWER LLANDEILO)



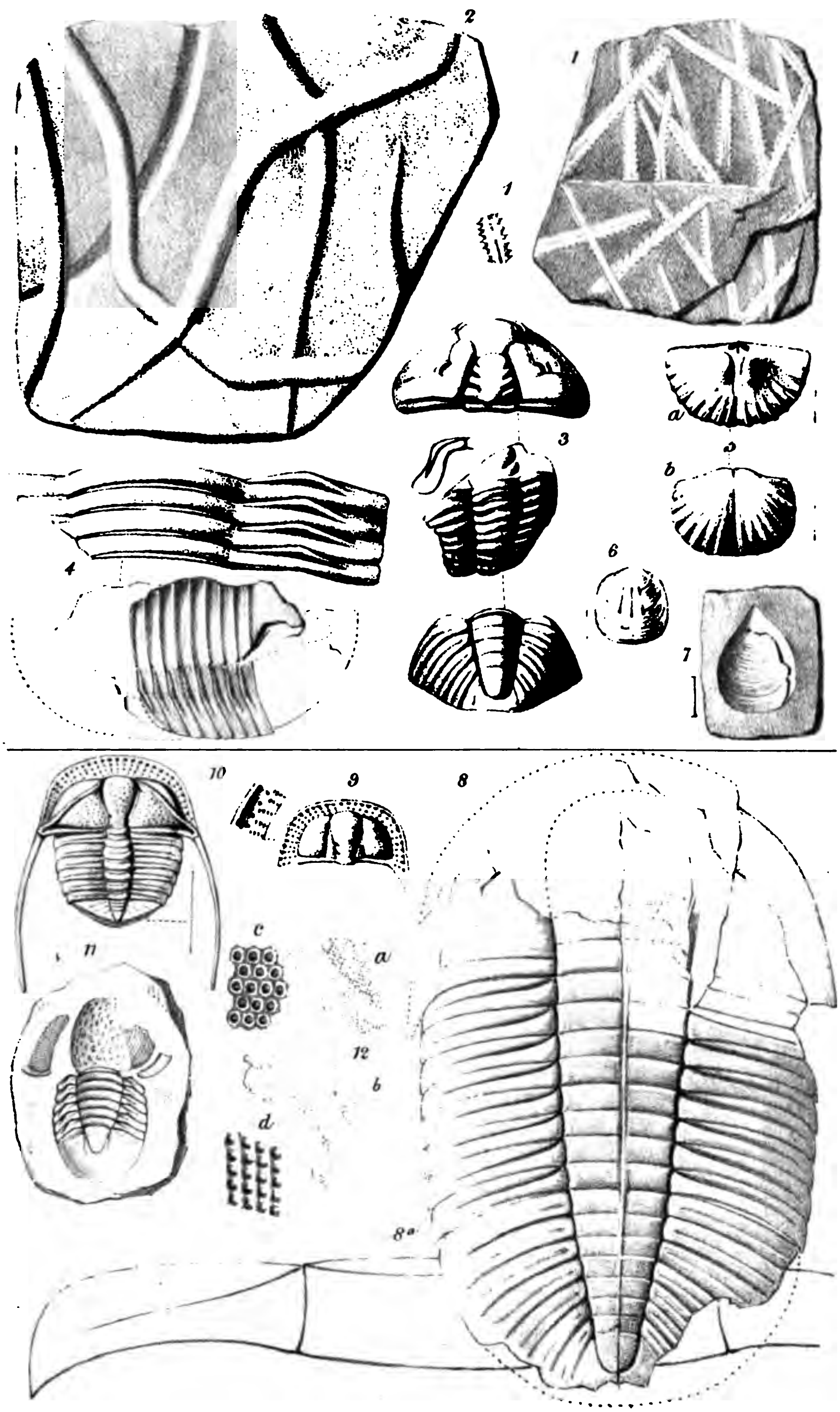
C.R. Bone del et lith. J.W. Salter direxit

Day & Son, Lith. to the Queen

1.2. ILLŒNUS ??
3. ÆGLINA BINODOSA. n. sp.
4. TRINUCLEUS MURCHISONI. n. sp.
5. OGYGIA SELWYNII Salter
6.8. DIDYMOGRAPSUS 9, CYATHOCRINUS PLUMBEA. Salter.

15. CUCULLELLA ANGLICA. n. sp.
16. RIBIERIA COMPLANATA. Salter
17. PALŒARCA AMYGDALUS. n. sp.
18. 20. ORTHOCERAS, 2 sp. 21. OPHILETA
22. 26. THECA SIMPLEX. n. sp.
27. WORM-BURROWS (SCOLITHUS)

Geological Survey of the United Kingdom. LOWER LLANDEILO.



C.R. Bone, del. _ J.W. Salter, direxit

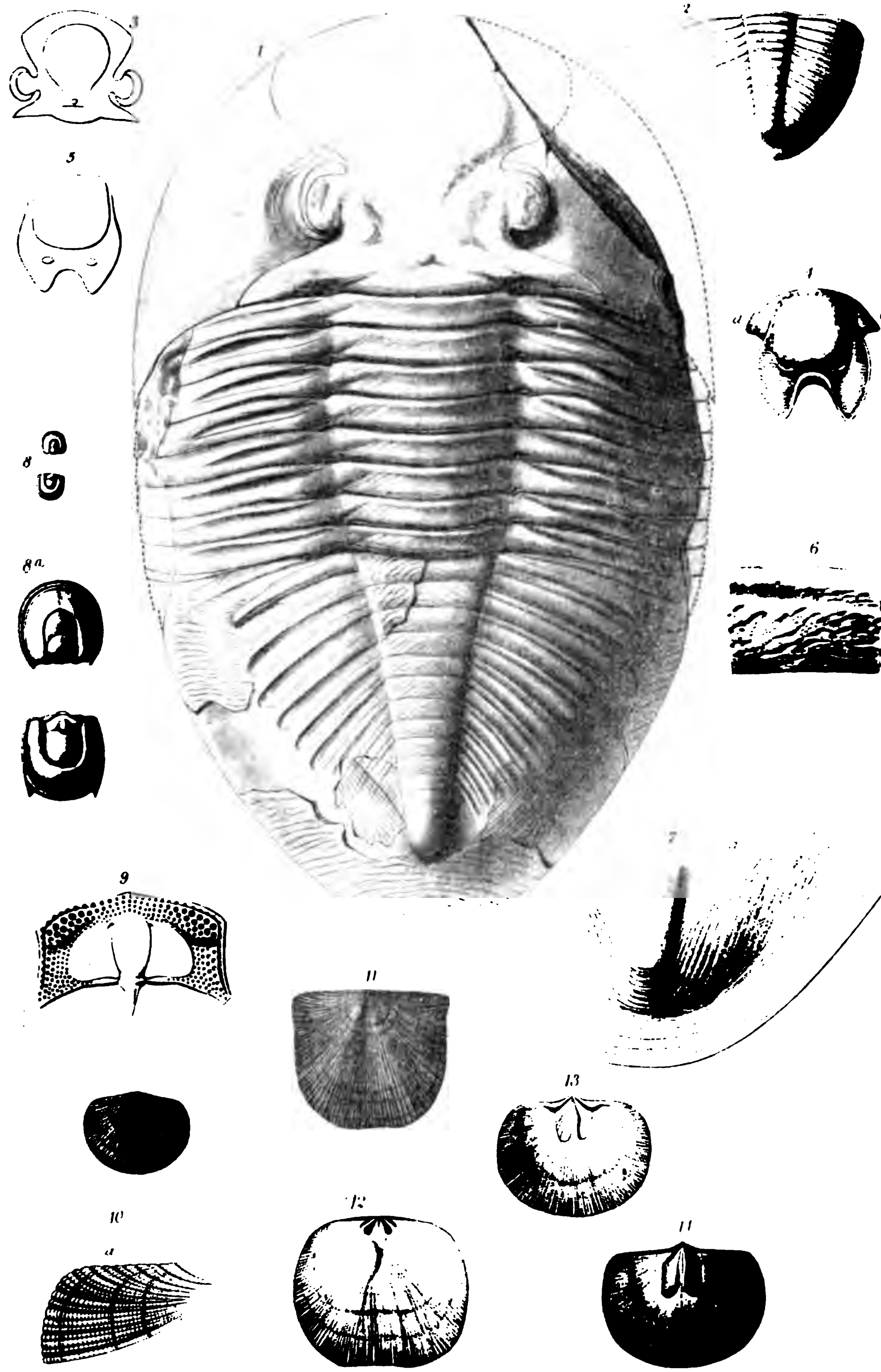
Day & Son, Lithrs to the Queen

1, 1a. DIPLOGRAPSUS _ 2 sp.
2. ANNELIDE BURROWS
3. CALYMENE PARVIFRONS, Salter
4. ASAPHUS AFFINIS _ McCoy.
5. ORTHIS CALLIGRAMMA _ Dalman
6.7. OBOLELLA
8. OGYGIA PELTATA Salter.
9.10. TRINUCLEUS _ 2 sp.
11.12. ÆGLINA, _ 2. sp.

PLATE 13.

Geological Survey of the United Kingdom.

LLANDEILO FLAGS.



C.R. Bone & W.H. Baily del. J.W. Lowry, sculp

Transferred by Day & Son, Lith[rs] to the Queen

CARADOC or BALA BEDS

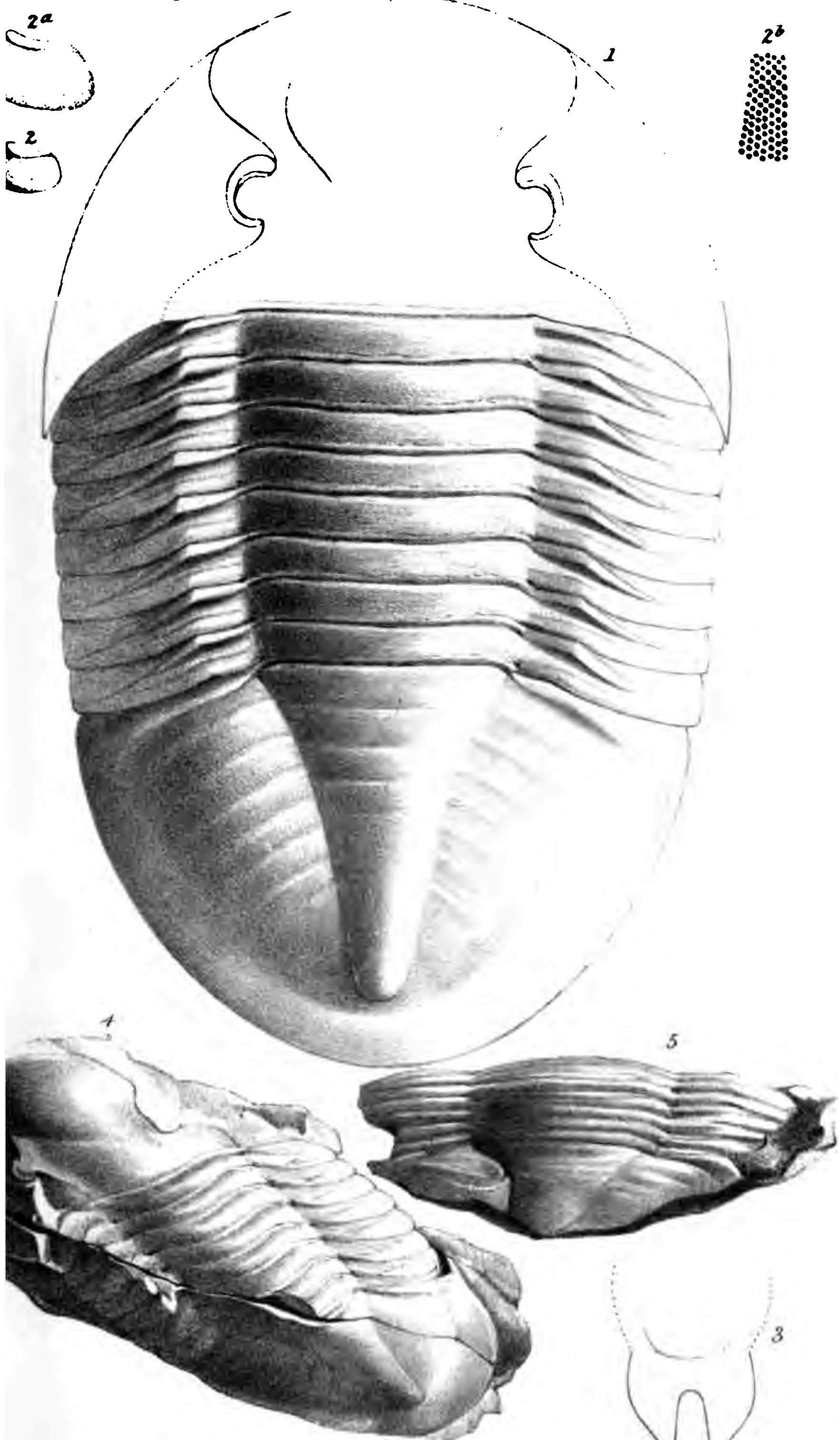
R. C. Bone ... del. ... Day & Son ... Lith.

1_4, ANNELIDE TUBES AND (FUCOIDS ? : Fig 5.6.)
in Sandy Slate, ... Bala, North Wales

logical Survey of the United Kingdom

PLATE

CARADOC
or BALA BEDS.



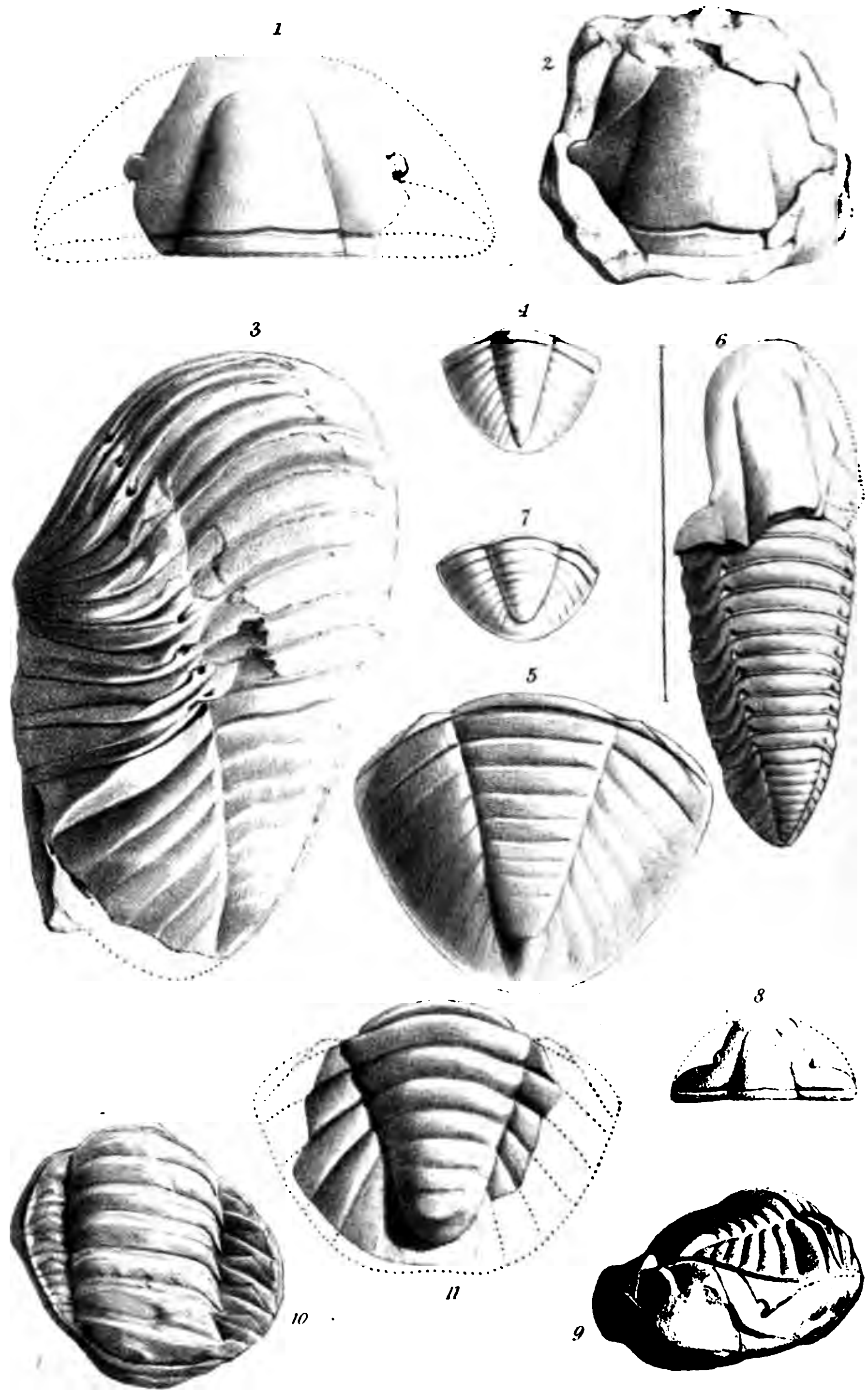
Day & Son, Lith.rs to the Queen.

ASAPHUS POWISII. _ *Murch.*

Geological Survey of the United Kingdom.

PLATE [illegible]

CARADOC or BALA BEDS.



C. R. Bone del. et lith.

Day & Son, Lith^rs to The Queen.

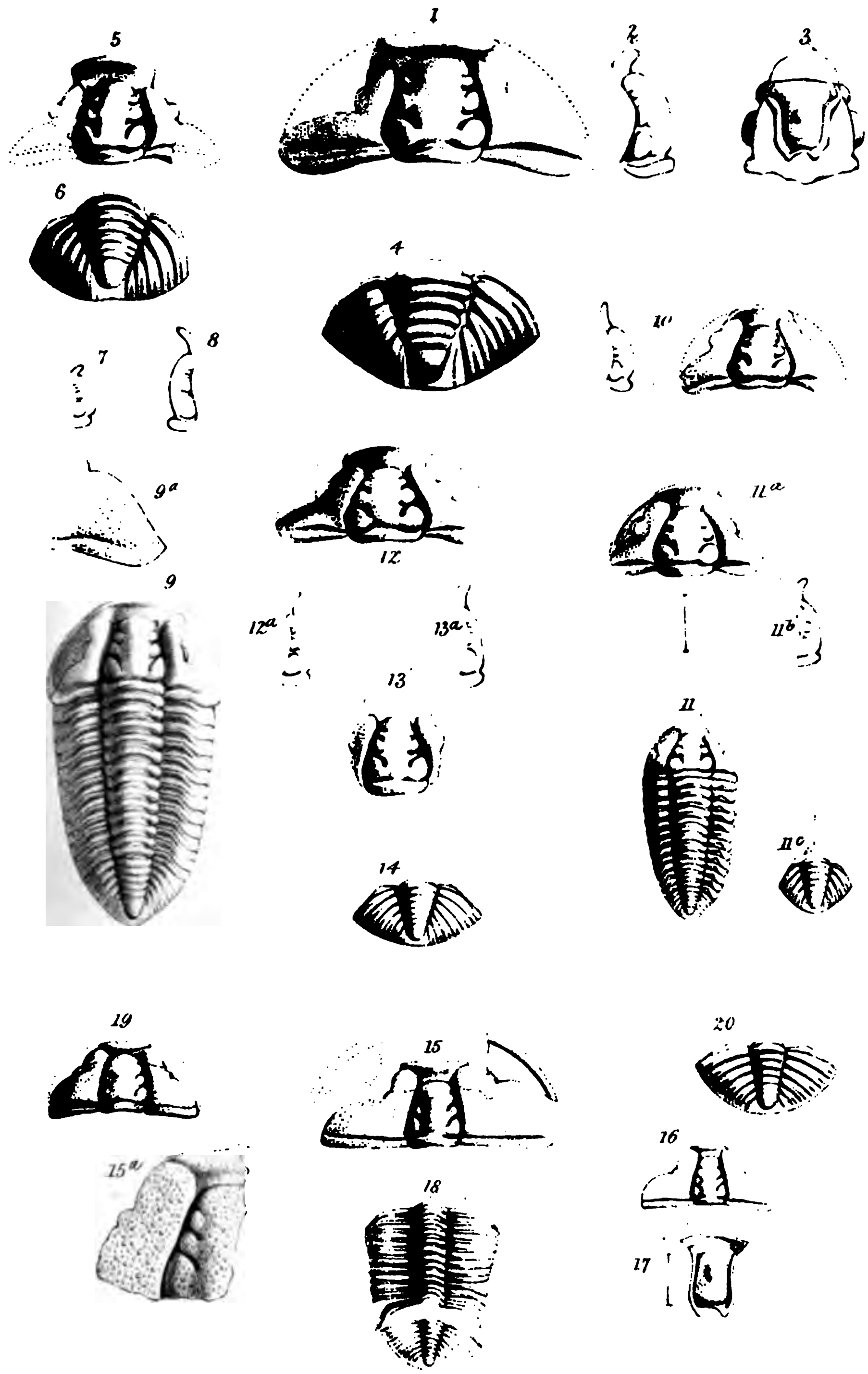
1 _ 8. HOMALONOTUS BISULCATUS _ *Salter*.

9 _ 11. „ RUDIS _____ _ *id*.

PLATE 17.

Geological Survey of the United Kingdom.

CARADOC
or BALA BEDS.



C. R. Bone del. et lith.

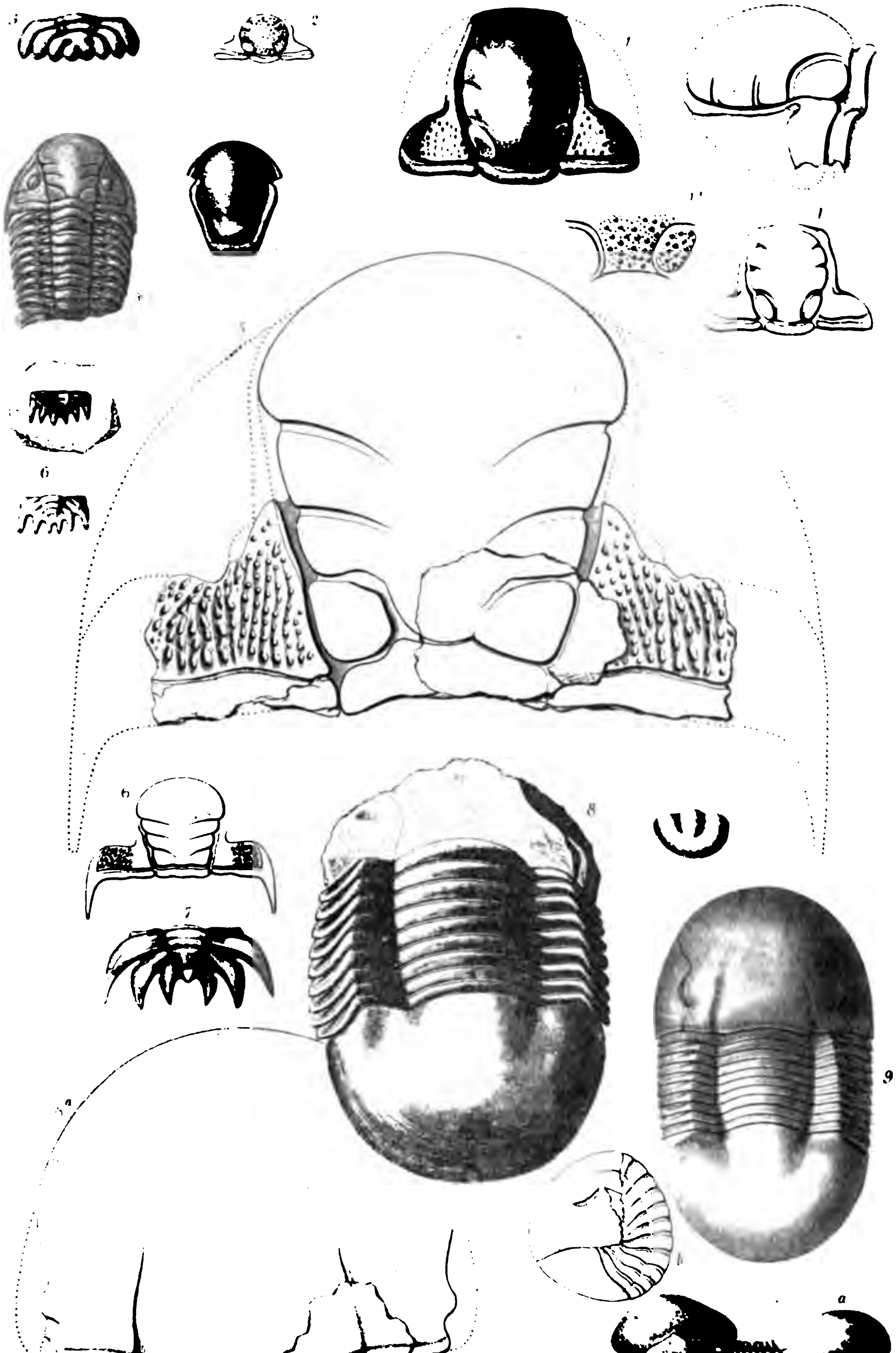
Day & Son Lithrs to The Queen.

1 _ 7	CALYMENE	BLUMENBACHII	*Brongn.*
8 _ 12	"	VAR. BREVICAPITATA	*Portlock*
13, 14	"	VAR. CAMBRENSIS	*Salter.*
15 _ 20	"	DUPLICATA	Murch.

PLATE 18

Geological Survey of the United Kingdom.

CARADOC or BALA BEDS.



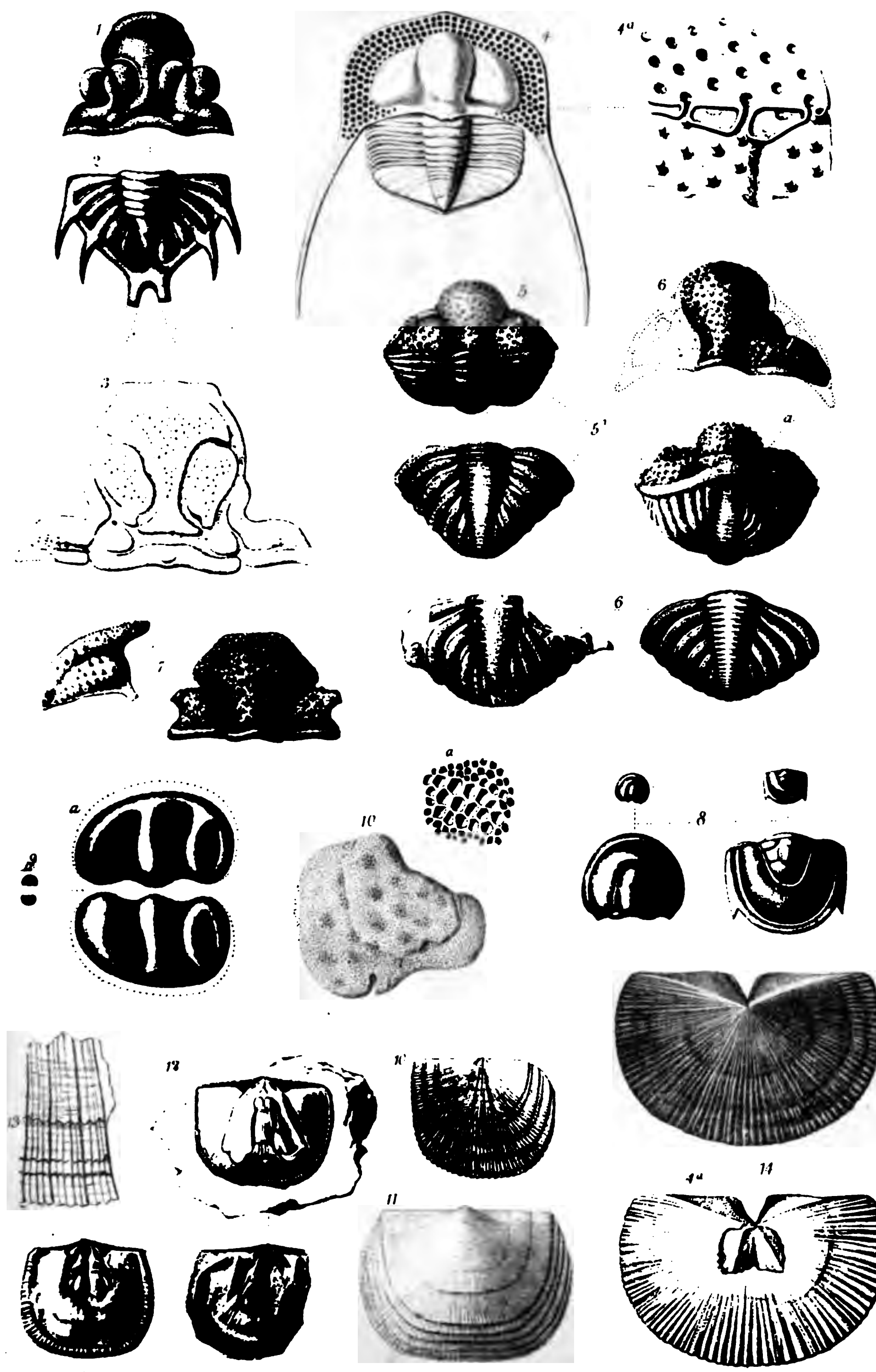
C R Bone & W H Baily del. J W Lowry sculp

Transferred by Day & Son Lithrs to the Queen

PLATE 19.

Geological Survey of the United Kingdom.

CARADOC or BALA BEDS.

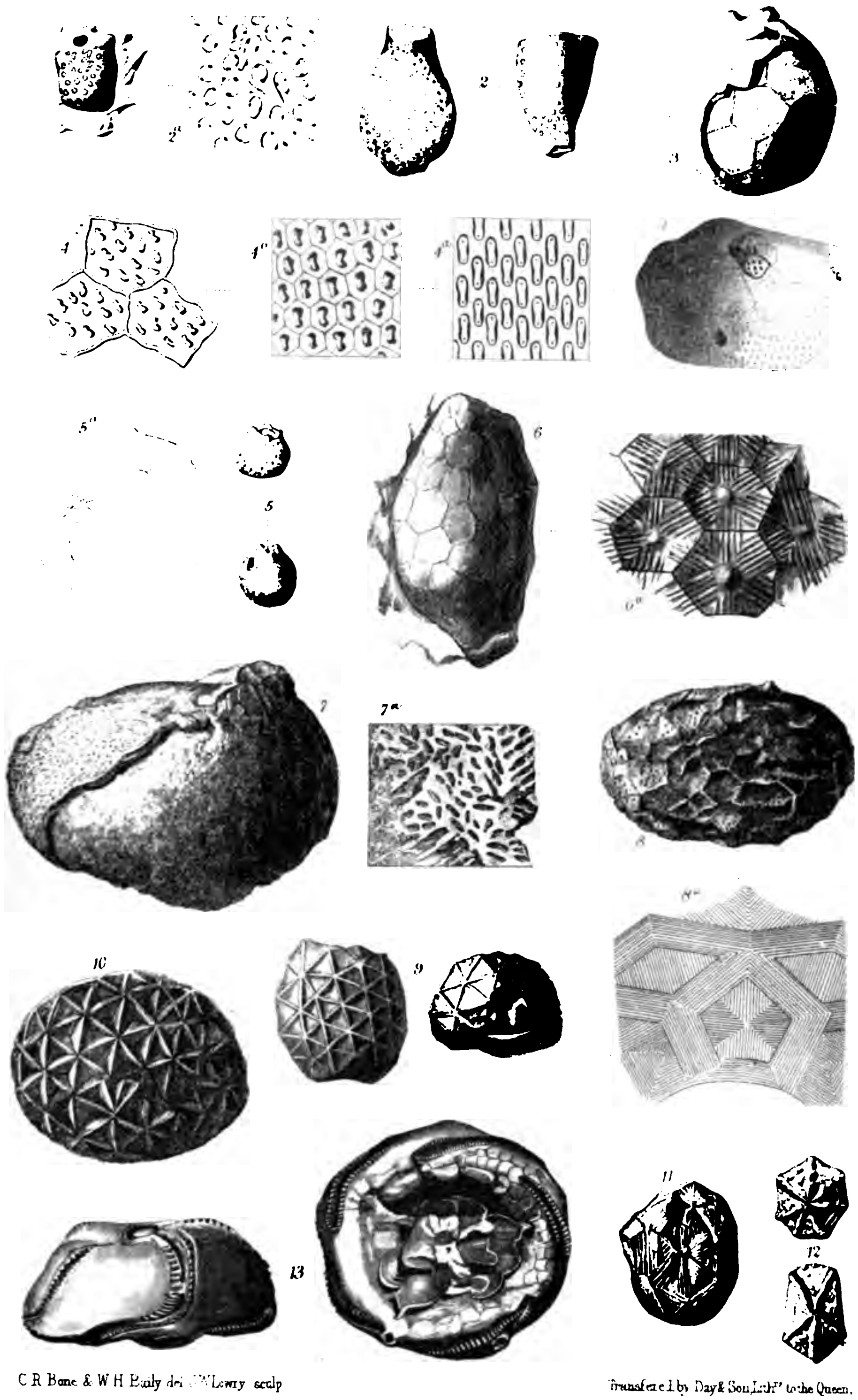


C. R. Bone & W. H. Baily, del. J. W. Lowry, sc.

Transferred by Day & Son, Lith[rs] to the Queen.

Geological Survey of the United Kingdom.

CARADOC or BALA BEDS.

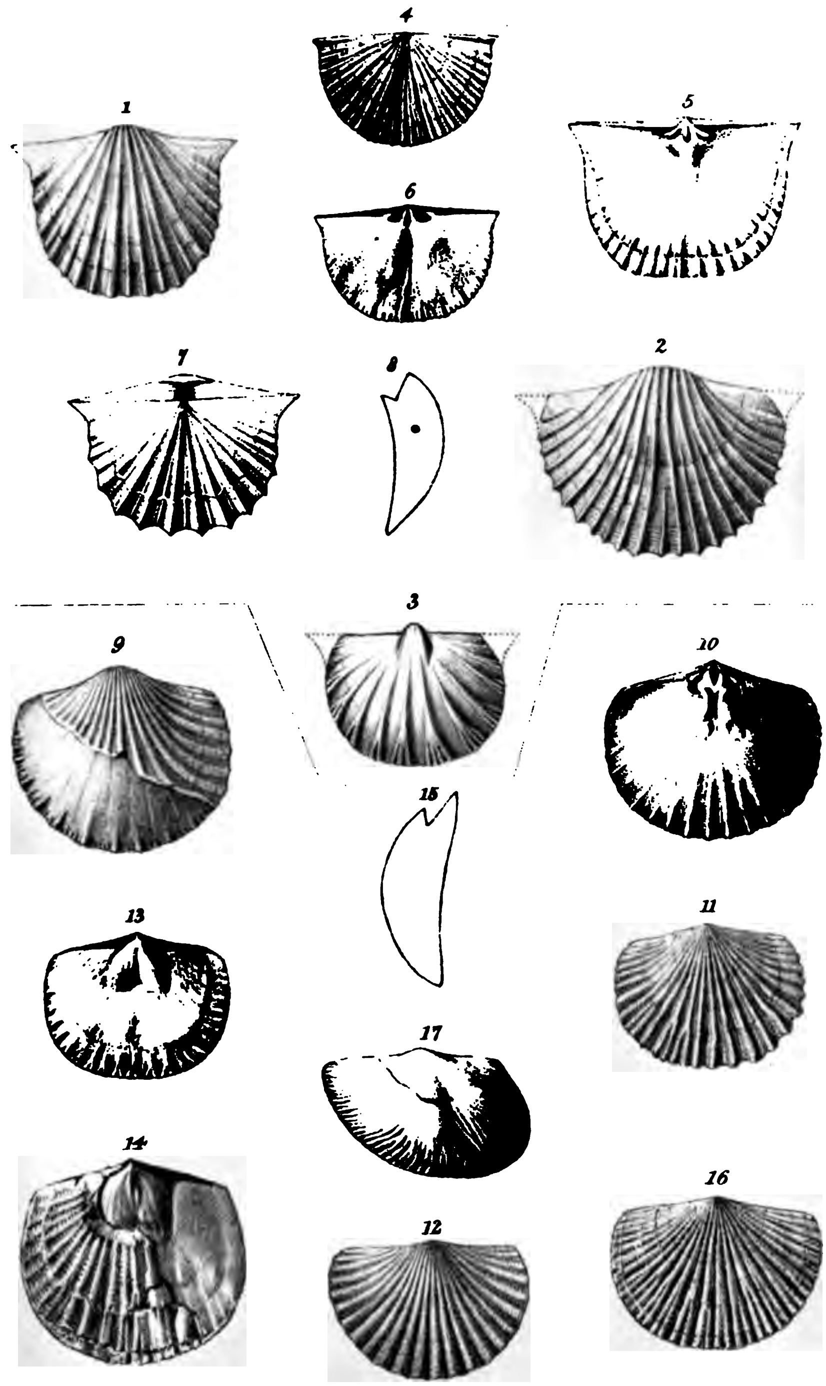


C R Bone & W H Baily del. J W Lowry sculp

Transferred by Day & Son, Lithrs to the Queen.

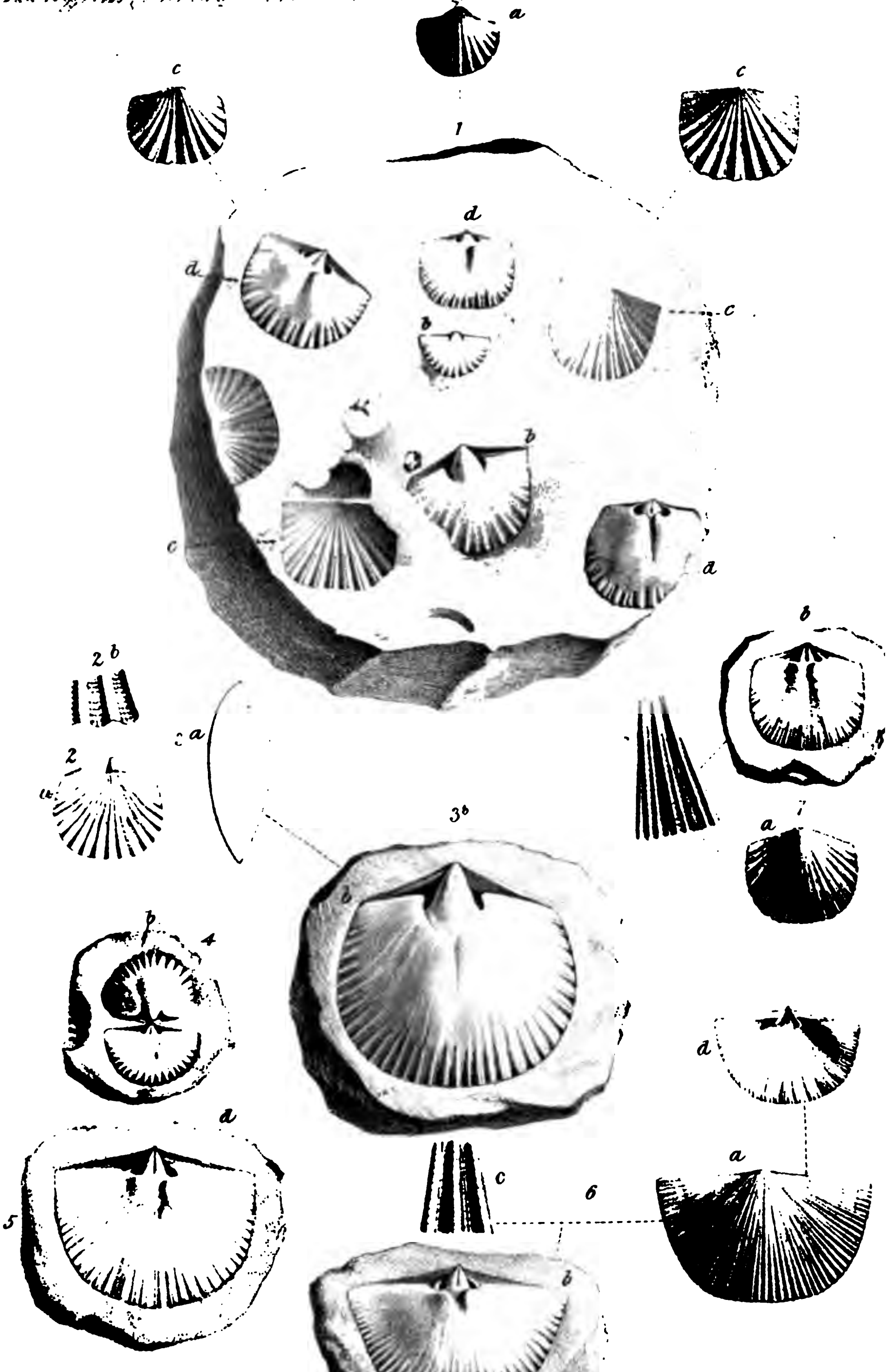
Geological Survey of the United Kingdom.

CARADOC or BALA BEDS.



R C Bone del et lith.

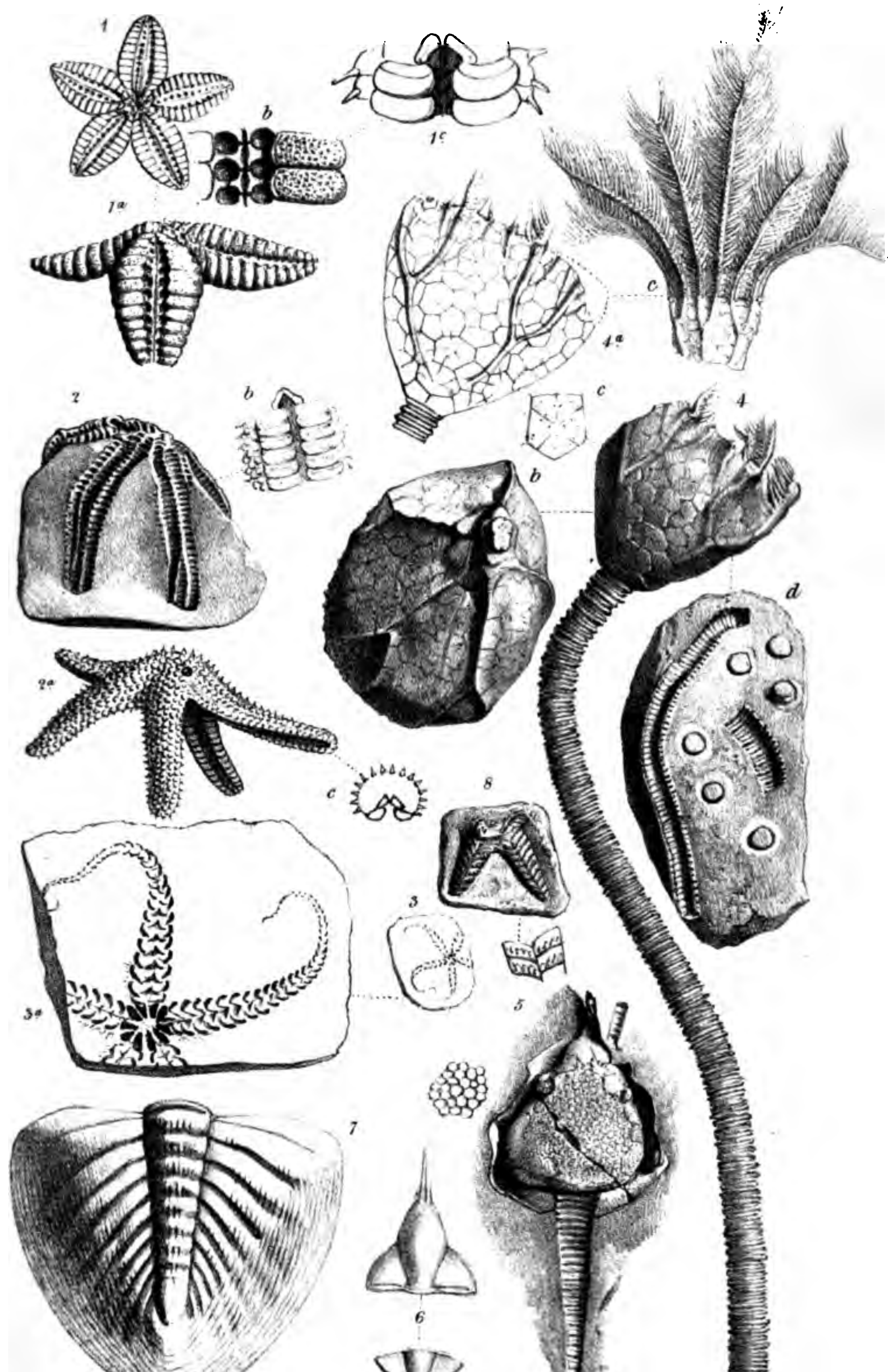
I. 8. ORTHIS ACTONIÆ. — Sow.
9. 16 ——— FLABELLULUM. — Sow.



C.R. Bone del et lith. J.W. Salter, direxit

Day & Son, Lith.rs to the Qu.

ORTHIS CALLIGRAMMA, *Dalman*; VAR. *Proava*. 2. D° VAR. *Calliptycha* M'Coy (*Plana*, *Pander*? 3. D° VAR. *Virgata*, J. D C. Sby. 4. VAR *Simplex*, M'Coy (*Orthambonites*, *De Vern*.) 5 VAR. *Plicata*, Sby 6,7, VAR. *Wallsalliensis*, *Davidson*?

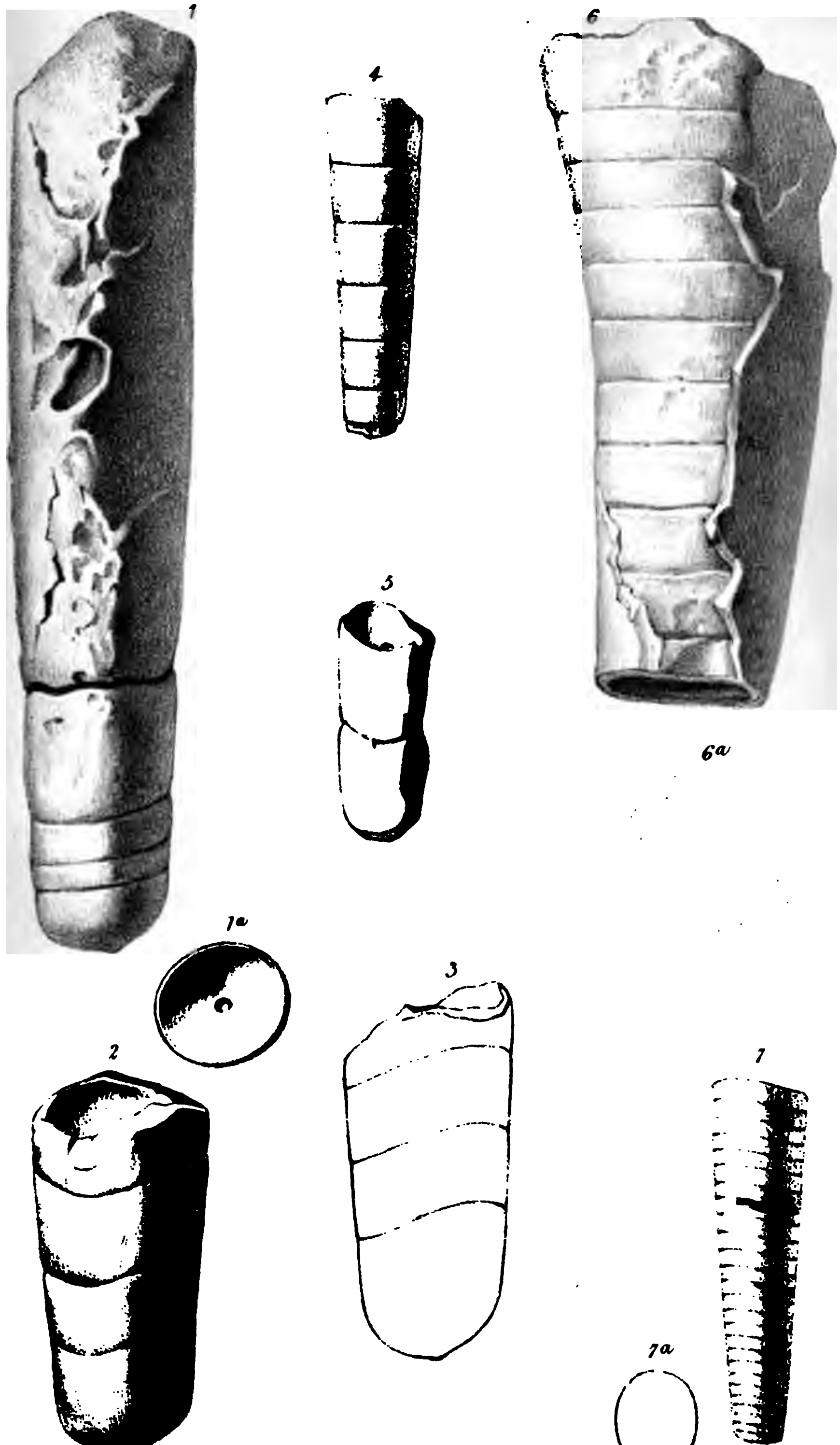


C.R. Bone del. _ J.W. Salter direxit.

Day & Son, Lithrs to the Queen.

1. PALŒASTER OBTUSUS _ *Forbes*
2. P. _ ASPERRIMUS _ *n. sp.*
3. PROTASTER SALTERI _ *Forbes*
4. GLYPTOCRINUS? BASALIS _ *Mc Coy*
5. PLEUROCYSTITES RUGERI _ *n. sp.*
6. AMPYX TUMIDUS _ *Forbes*
7. ASAPHUS RADIATUS _ *Salter*
8. PALŒASTER IMBRICATUS, *n. sp.*

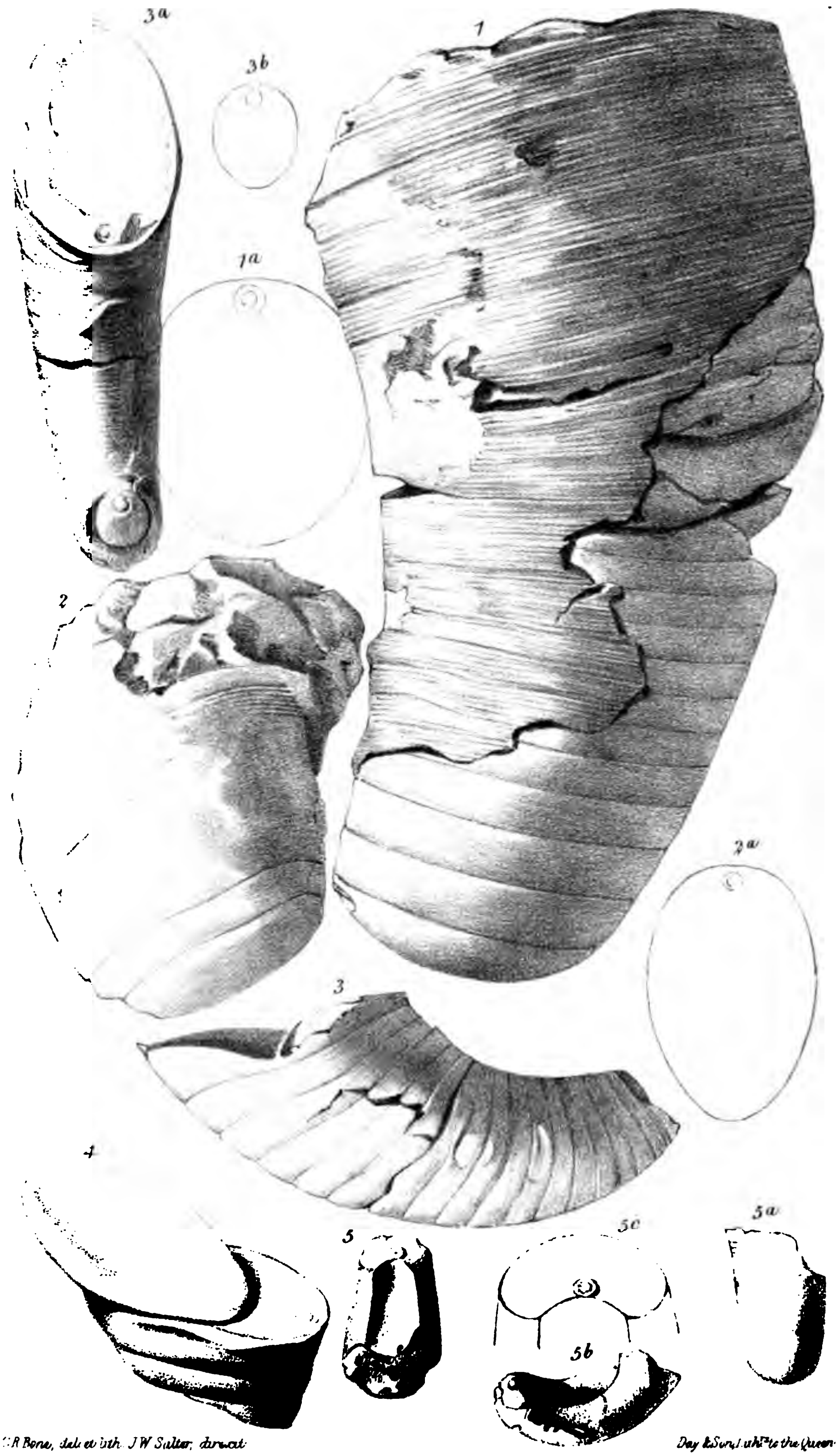
Geological Survey of the United Kingdom. (CARADOC OR BALA)



C.R.Bone, del et lith, J.W.Salter, direxit — Day & Son, Lith^rs to the Queen

1–5. ORTHOCERAS VACANS. *Salter.* — 6. ORTHOC. — sp.
7. O. AUDAX, *Salter.*

Geological Survey of the United Kingdom. (CARADOC OR BALA)

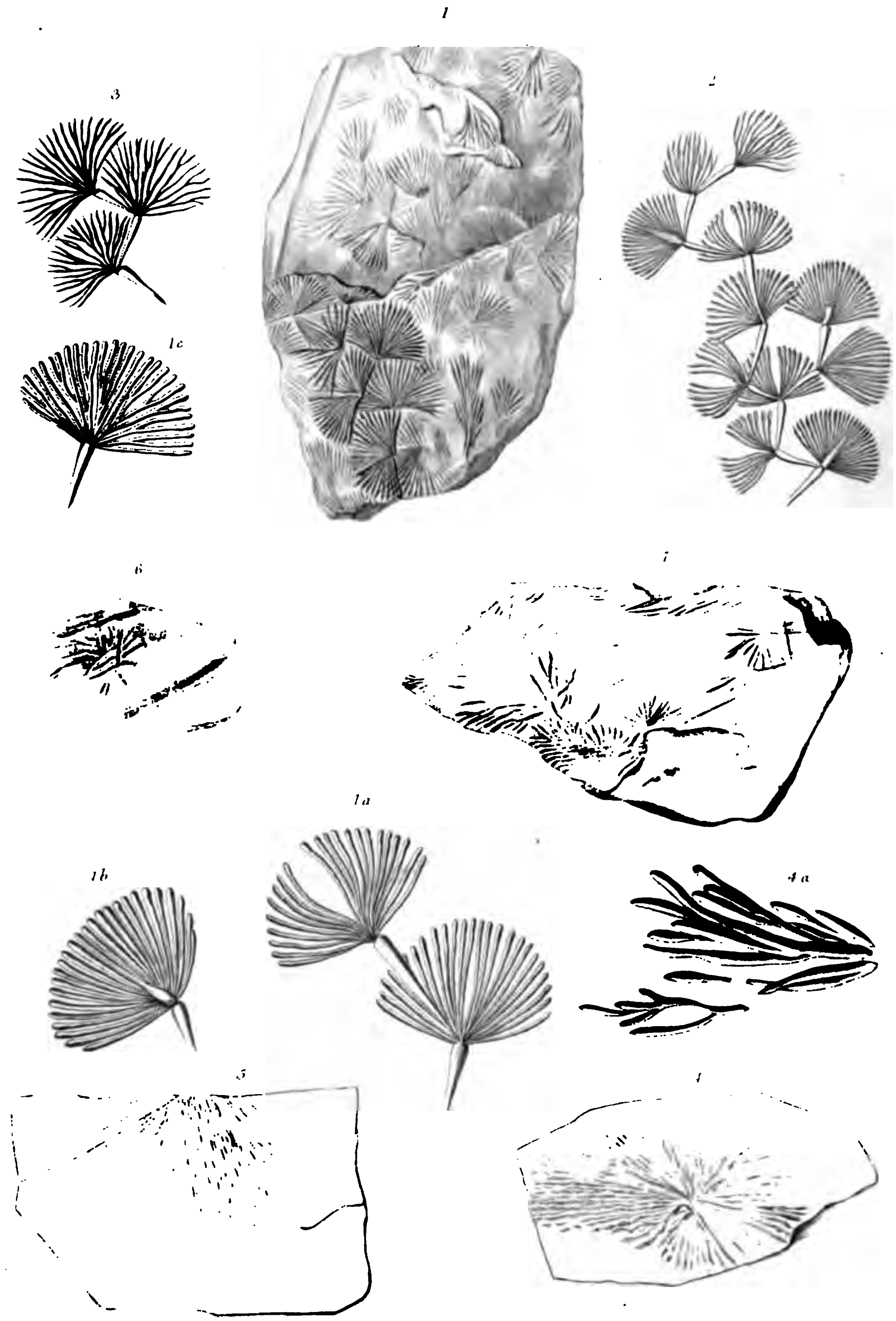


C.R Bone, del. et lith. J.W Salter, direxit — Day & Son, Lithrs to the Queen

I CYRTOCERAS SONAX _ *n. sp.* | 2,3,4, C. ATRAMENTARIUM. *n. sp.*
5. *LITUITES (TROCHOLITES) PLANORBIFORMIS, Conrad*

Geological Survey of the United Kingdom.

OLDHAMIA
(Cambrian)



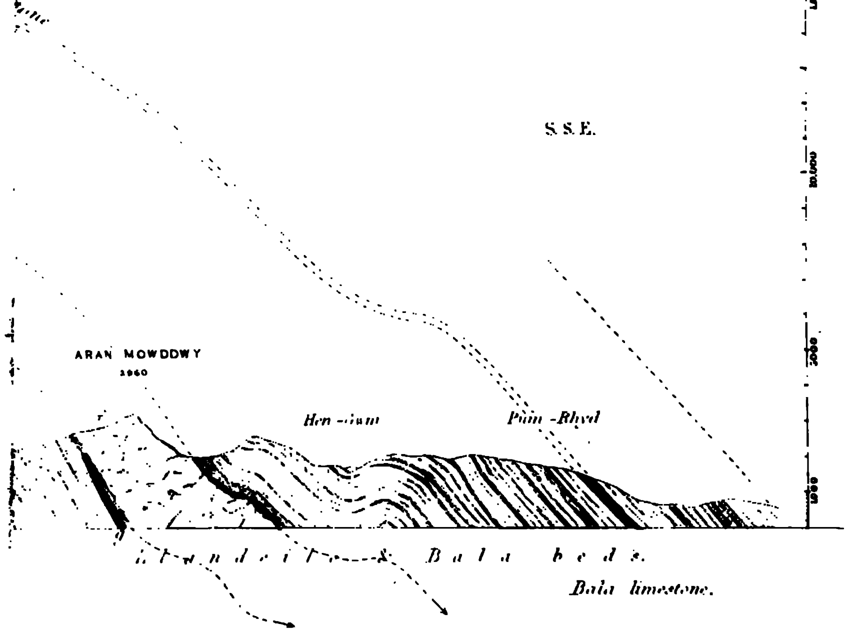
1, 3 OLDHAMIA ANTIQUA *Forbes*
4, 5 — RADIATA *Forbes*
6, 7 — RADIATA *var.*

...shire.

S.E.

...d with felspathic lavas and ashes 3 to 6,
...phyry F. and greenstones g.

S.S.E.



...Llandeilo & Bala beds.
Bala limestone.

Engraved by J. W. Lowry.

LONDON:
Printed by George E. Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.
[12832.—500.—2/66.]